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Evaluation of Continuous Monitors for Carbon Monoxide in Stationary Sources

Scott Environmental Technology, Inc, Plumsteadville, Pa

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EVALUATION OF CONTINUOUS MONITORS FOR CARBON MONOXIDE IN STATIONARY SOURCES

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The performance characteristics of five commercially available continuous carbon monoxide monitors were evaluated in a two part program. This consisted of a laboratory and a field phase. The laboratory phase involved testing each instrument for response characteristics, precision, noise, response times, drifts, variations due to temperature and pressure, and CO_2 and H_2O interferences. The field evaluation phase involved the operation of the monitors on the outlet duct of a carbon monoxide boiler at a petroleum refinery. Data generated in both phases of the program was used as the basis for recommending minimum performance specifications for continuous carbon monoxide monitors at petroleum refineries.

This report was submitted in fulfillment of Contract No. 68-02-1406, Task 20, by Scott Environmental Technology, Inc. under the sponsorship of the U. S. Environmental Protection Agency. This report covers a period from July 1, 1975 to March 1, 1976, and work was completed as of October 14, 1976.

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SECTION 1

INTRODUCTION

This is the final report describing the results of an evaluation of continuous carbon monoxide monitors for stationary sources. Work was performed by Scott Environmental Technology, Inc. for the U.S. Environmental Protection Agency under task order Contract 68-02-1400, Task No. 20. The evaluation program consisted of both laboratory and field performance phases.

The objectives of the program were to establish the laboratory and field performance characteristics of each of five commercially available instruments. Based on this data, minimum performance specifications for carbon monoxide monitors as applicable to petroleum refineries are recommended. Additionally, recommendations regarding maintenance and calibration of these monitors are made based on the field performance evaluation.

Five commercially available continuous carbon monoxide monitors were selected employing three different detection techniques. The instruments included: two non-dispersive infrared analyzers, a gas chromatographic analyzer with flame ionization detector, an in-situ cross stack analyzer with an infrared source and an instrument employing an electrochemical detector. The specific analyzers selected for the program are presented in Table 1.

The laboratory evaluation phase of the program consisted of a series of performance tests conducted on each instrument. These tests included the response characteristics, precision, noise, response times, drifts, variations due to temperature and flow rates, and CO_2 and H_2O interferences.

The field evaluation phase was performed on the outlet of two carbon monoxide boilers at an east coast oil refinery. The instruments were installed in a trailer parked at the site, and monitoring ran continuously from December 1, 1975 to January 23, 1976. Carbon monoxide emission concentrations from this source averaged about 500 ppm during the program.

TABLE 1. PROJECT IDENTIFICATION

Manufacturer	Model	Serial No.	Description
Environmental Research and Technology, Inc.	Stack Gas Analyzer Model 4000		Multi-component in-situ cross stack analyzer using infrared source
Energetics Science Inc.	Analyzer Model 3300	3313	Continuous carbon monoxide monitor employing electrochemical detector
Beckman	Model 6800	1001119	Multi-component automated chromatograph with flame ionization detector
Beckman	Model 865	0100230	Non-dispersive infrared analyzer
Bertha *	A2A-2 and A2A-2165	3062 4150/301	Non-dispersive infrared analyzer

* A2A-2 was replaced by A2A-2165 during field evaluation phase.

SECTION 2

CONCLUSIONS

2.1 DISCUSSION

This evaluation program for continuous carbon monoxide monitors has demonstrated that currently available instrumentation is capable of producing reliable continuous data within reasonable performance specifications. Instrument reliability, however, has been shown to be a weak point in a field monitoring situation over extended periods of time.

The Beckman Model 6800 chromatograph and the Horiba Model AIA-21AS NDIR performed satisfactorily both overall and with respect to the recommended specifications. Failure of the remaining instruments to meet one or more of the recommended specifications was generally related to maintenance problems in the field. However, the maintenance records for the program instruments show that each category of instrumentation whether it be chromatographic, NDIR, cross stack (in situ) or electrochemical had malfunction or maintenance related problems during the field program. In several cases, these malfunctions resulted in a significant amount of down-time and resultant lost data. Considering the maintenance requirements demonstrated by this evaluation program, a regular maintenance program or method of insuring that the instruments are well maintained should be required and considered as important as any of the performance criteria in terms of obtaining reliable continuous data.

Relative accuracy determinations presented in the following section, were made using three instruments as references. Modified Method 10 carbon monoxide determinations using the continuous sampling procedure supplied the reference data. The modifications included elimination of the silica gel and ascarite traps for the NDIR's as moisture was effectively removed by a refrigerated coil condenser in the sampling system and the NDIR instruments in the program had negligible CO_2 interference (Tables 10 and 11). Relative accuracy determinations using the Beckman 6800 chromatograph as a reference instrument were made. This was done because the Beckman chromatograph has several advantages as a reference instrument over an NDIR including no interference, linear output, insensitivity to sample flow and pressure variations and

its overall superior performance as demonstrated in this program. In light of these advantages, the data produced by using this instrument as a reference in the relative accuracy determination was considered useful.

EPA presently requires daily calibration for continuous monitoring installations and it should be emphasized that these daily calibrations are a must for continuous carbon monoxide instrumentation. This program has demonstrated that several of the instruments are susceptible to significant zero and span drift which should be compensated for daily in order to optimize data quality. In addition to the data quality aspects of daily calibrations, they also serve as an important maintenance indicator and diagnostic tool. This daily calibration data may show up a deteriorating component, for example, thereby avoiding or minimizing needless system downtime.

2.2 PERFORMANCE TEST RESULTS

Summaries of the laboratory and field performance tests are presented in Tables 2 and 3, respectively. Performance test methodologies are described in Section 3.1 for laboratory tests and Section 3.2 for field performance tests.

The specific field performance results for each instrument are presented in the following tables:

Table 4 Relative Accuracy
- A Beckman 865 Reference
- B Bertha AIA-21AS Reference
- C Beckman 6800 Reference

Table 5 Zero and Calibration Drift (24 Hour)

TABLE 2. [illegible]

Parameter	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Range	0-1000	0-1000	0-1000	0-1000	0-1000	0-1000
Calibration Linearity (% Full Scale)	0	5.0	0	0.0	6.0	12.5
Precision (% Full Scale)	*	0.43	0.14	0.77	0.77	0.34
Noise (% Full Scale) rms ul/span	3.6	0.346 / 0.76	36	0.05 / 0.084	*	0.05 / 0.7
Rise/Fall Times (Seconds)	*	96 / 83	36	5.4 / 6.5	10.9 / 9.4	7.9 / 10.0
Zero Drift 24 Hr. (% Full Scale)	*	0.2	0	0.4	1.2	0.39
Zero Drift 12 Hr. Continuous (% Full Scale)	*	0.6	0	0.44	0	0.49
Span Drift 0 Hr./24 Hr. (% Full Scale)	*	* / 0.4	0.7 / 0.8	0.9 / 1.4	* / 0.5	0.7 / 0.46
Interference Equivalent (ppm) [illegible]	20 / 5	0 / *	0 / 0	3.4 / 1.7	48.9 / *	3.4 / 0.5

* : Tested

[illegible] : Applicable

TABLE 1. INSTRUMENT PERFORMANCE SUMMARY (FIELD)

Parameter	EMC	Intelligent	Rochester 6000	Rochester 903	Martin A10-2165
Relative Accuracy[1] (Rochester 903 Reference)	3.2	7.4	6.2		2.5
Relative Accuracy[1] (Martin A10-2165 Reference)	29.6	4.1	5.1	2.5	
Relative Accuracy[1] (Rochester 6000 Reference)	11.4	4.6		6.5	5.8
Response Time (Minutes)	<1	<2	<6	<1	<1
Zero Drift, 24 Hours[1] (% Full Scale)	*	3.9	0	2.6	0.5
Zero Drift, 2 Hours[1] (% Full Scale)	*	0.7	0	0.3	0.34
Span Drift, 24 Hours[1] (% Full Scale)	*	8.5	0.0	4.5	1.1
Operational Period (Hours)	<168	<168	>193	<168	>168

* Insufficient Data

1. Expressed as sum of absolute mean value plus 95% confidence interval of a series of tests.

TABLE 4A. RELATIVE ACCURACY - [illegible] REFERENCE

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	[illegible] 15 Minute Average PPM
11/13	2430	637.0	634.0
	0130	636.6	643.0
	0230	637.7	629.0
	0330	652.0	671.0
	0430	668.5	671.0
	0530	658.0	661.0
	0630	635.5	621.0
	0730	626.3	597.0
	0830	619.0	582.0

Mean Reference Value = 640.5 PPM
Mean Difference = 12
95% Confidence Interval = 8.1
Relative Accuracy = 3.3%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	Analyzer 15 Minute Average PPM
12/13	0630	633.5	622.0
	0730	626.3	605.0
	0830	619.0	596.5
	0930	598.4	567.0
	1030	590.1	567.0
	1130	571.6	580.0
	1230	529.0	470.0
	1330	642.8	627.0
	1430	644.8	622.0

Mean Reference Value = 605.1
Mean Difference = 38.6
95% Confidence Interval = 14.4
Relative Accuracy = 7.4%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	Beckman 6800 15 Minute Average PPM
12/13	0630	633.5	630.1
	0730	626.3	585.5
	0830	619.0	578.4
	0930	598.4	579.4
	1030	590.1	553.8
	1130	571.6	527.8
	1230	529.0	584.2
	1330	642.8	629.8
	1430	644.8	638.3

Mean Reference Value = 605.1
Mean Difference = 26.5
95% Confidence Interval = 11.2
Relative Accuracy = 6.2%

Date	Time (Ending 15 Minute Interval)	Reference Beckman 865 15 Minute Average PPM	Servomex 4004-2DAS 15 Minute Average PPM
12/21	1430	320.0	320.0
	1530	310.0	302.0
	1630	316.0	315.0
	1730	372.0	380.0
	1830	399.0	372.0
	1930	480.0	472.0
	2030	340.0	340.0
	2130	323.0	335.0
	2230	309.0	318.0

Mean Reference Value = 359.0
Mean Difference = 4.0
95% Confidence Interval = 3.6
Relative Accuracy = 2.5%

TABLE 4A. RELATIVE ACCURACY - MONITOR AQA-2165 REFERENCE

Date	Time (Ending 15 Minute Interval)	Ref.-Aerolbe AQA-2165 15 Minute Average ppb	[illegible] 15 Minute Average ppb
12/24	1430	285.0	402.4
	1530	311.0	342.2
	1630	311.0	337.6
	1730	285.0	321.9
	1830	297.0	296.0
	1930	285.0	328.4
	2030	796.0	296.8
	2130	291.0	360.8
	2230	291.0	425.5

Mean Reference Value = 294.7
Mean Difference = 32.2
95% Confidence Interval = 15.6
Relative Accuracy = 29.8%

Date	Time (Ending 15 Minute Interval)	Ref.-Aerolbe AQA-2165 15 Minute Average ppb	Analyzer 15 Minute Average ppb
12/24	1530	285	310
	1630	297	310
	1730	285	300
	1830	296	305
	1930	291	297
	2030	291	300
	2130	297	292
	2230	299	310
	2330	297	310

Mean Reference Value = 293.1
Mean Difference = 11.8
95% Confidence Interval = 6.1
Relative Accuracy = 6.1%

Date	Time (Ending 15 Minute Interval)	Ref.-Aerolbe AQA-2165 15 Minute Average ppb	Aerolaser 6400 15 Minute Average ppb
12/21	1430	320	336.2
	1530	302	299.8
	1630	315	311.8
	1730	380	360.3
	1830	372	367.3
	1930	402	415.6
	2030	340	335.5
	2130	335	346.7
	2230	328	315.8

Mean Reference Value = 342.7
Mean Difference = 11.8
95% Confidence Interval = 6.5
Relative Accuracy = 3.3%

Date	Time (Ending 15 Minute Interval)	Ref.-Aerolbe AQA-2165 15 Minute Average ppb	Analyzer 6400 15 Minute Average ppb
12/21	1430	320.0	336.0
	1530	302.0	310.0
	1630	315.0	326.0
	1730	380.0	372.0
	1830	372.0	368.0
	1930	402.0	408.0
	2030	340.0	340.0
	2130	335.0	323.0
	2230	328.0	306.0

Mean Reference Value = 342.7
Mean Difference = 4.0
95% Confidence Interval = 3.6
Relative Accuracy = 2.5%

TABLE 4C. RELATIVE ACCURACY - HOURLY NOX AVERAGES

Date	Time (Ending 15 Minute Interval)	Reference Analyzer 4000 15 Minute Average (ppb)	SRT 15 Minute Average (ppb)
12/9	0230	264.1	263.6
	0330	288.6	268.3
	0430	325.1	277.5
	0530	268.7	268.3
	0630	257.5	240.5
	0730	256.8	259.0
	0830	255.2	245.1
	0930	264.4	259.0
	1030	278.8	260.5

Mean Reference Value = 268.0
Mean Difference = 19.3
95% Confidence Interval = 11.5
Relative Accuracy = 11.4%

Date	Time (Ending 15 Minute Interval)	Reference Analyzer 4000 15 Minute Average (ppb)	Analyzer 15 Minute Average (ppb)
12/6	0130	435.0	425.4
	0230	428.3	398.5
	0330	395.6	425.3
	0430	402.6	421.5
	0530	407.0	427.6
	0630	396.0	408.3
	0730	438.7	438.2
	0830	478.1	478.4
	0930	457.4	476.5

Mean Reference Value = 425.0
Mean Difference = 13.2
95% Confidence Interval = 6.6
Relative Accuracy = 4.6%

Date	Time (Ending 15 Minute Interval)	Reference Analyzer 4000 15 Minute Average (ppb)	Analyzer 965 15 Minute Average (ppb)
12/13	0630	630.1	633.5
	0730	595.5	626.3
	0830	578.4	619.0
	0930	579.4	598.4
	1030	553.6	580.1
	1130	527.6	571.6
	1230	586.2	559.0
	1330	629.6	642.8
	1430	618.3	644.8

Mean Reference Value = 578.6
Mean Difference = 26.5
95% Confidence Interval = 11.2
Relative Accuracy = 6.5%

Date	Time (Ending 15 Minute Interval)	Reference Analyzer 4000 15 Minute Average (ppb)	Horiba AIA-210S 15 Minute Average (ppb)
12/22	1430	336.2	328.0
	1530	294.6	302.0
	1630	311.6	325.0
	1730	360.3	361.0
	1830	367.3	372.0
	1930	415.6	402.0
	2030	355.5	340.0
	2130	346.7	335.0
	2230	315.8	319.0

Mean Reference Value = 346.6
Mean Difference = 11.0
95% Confidence Interval = 6.5
Relative Accuracy = 5.3%

TABLE 5. ZERO & SPAN DRIFT (24 HOUR)

Ecolyzer			Beckman 6800		
Date	AZ PPM	AS PPM	Date	AZ PPM	AS PPM
12/18	0	-30.0	12/2		1.0
12/19	0	52.6	12/3		3.0
12/20	19.6	0.7	12/4		4.0
12/21	-66.9	-28.7	12/5		-9.9
12/22	17.1	128.3	12/6		0
12/23	11.9	67.5	12/7		9.9
12/24	9.0	-16.3	12/8		2.0
E	124.1	132.9	E		31.8
Mean	17.8	47.5	Mean		4.5
95% Confidence Interval	21.2	37.8	95% Confidence Interval		3.6
Drift (% of Span)	3.9	8.5	Drift (% of Span)		0.8

Beckman 865			Horiba AIA-21AS		
Date	AZ PPM	AS PPM	Date	AZ PPM	AS PPM
1/11	-35.0	-65.0	1/11	-8.3	-9.2
1/12	-3.0	-10.1	1/12	-3.3	-13.4
1/13	-12.3	-17.4	1/13	-5.1	+5.0
1/14	+26.7	-20.7	1/14	0	-4.2
1/15	+9.3	+27.8	1/15	-1.7	-6.8
1/16	-13.4	-13.4	1/16	-5.2	-10.4
1/17	-10.0	-26.4	1/17	+1.8	+3.5
E	109.7	106.8	E	35.4	52.5
Mean	15.7	28.1	Mean	3.6	7.5
95% Confidence Interval	10.3	17.2	95% Confidence Interval	2.6	3.6
Drift (% of Span)	2.6	4.3	Drift (% of Span	1.6	1.1

SECTION 3

RECOMMENDATIONS

3.1 PERFORMANCE SPECIFICATION

Recommended performance specifications for continuous carbon monoxide monitoring systems are presented in Table 3-1 below. These specifications are based on the overall performance demonstrated by the continuous monitors in this program, the results of the specific field performance tests, and a knowledge of the data quality requirements for continuous carbon monoxide monitoring.

TABLE 6. RECOMMENDED PERFORMANCE SPECIFICATIONS FOR CONTINUOUS MONITORS OF CARBON MONOXIDE AS APPLICABLE TO PETROLEUM REFINERIES

Parameters	Specifications
Range	0-1000 ppm
Calibration Linearity[2]	≤2% Span
Relative Accuracy[1]	≤10% Mean Ref. Value
Precision	≤1% Span
Response Time (System)	≤10 Minutes
Output Noise	≤1% span
Zero Drift, 2 Hours[1]	≤1% Span
Zero Drift, 24 Hours[1]	≤2% Span
Span Drift, 24 Hours[1]	≤2.5% Span
Interference Equiv. 15% CO_2/10% H_2O	≤10 ppm for 15% CO_2 ≤5 ppm for 10% H_2O
Operational Period	≥168 hours

1. Expressed as sumn of absolute mean value plus 95% confidence interval in a series of tests.
2. Based upon Engineering Judgement

The performance parameters specified in Table 6 are defined as follows:

Range - The minimum and maximum measurement levels.

Calibration Linearity - The maximum deviation of the instrument's calibration curve from a straight line drawn between the zero and full scale instrument responses. This value is expressed as a percentage of full scale.

Relative Accuracy - The degree of correctness with which the continuous monitoring system yields the value of gas concentration of a sample relative to the value given by a defined reference method.

Precision - Variation about the mean of repeated measurements of the same pollutant concentration, expressed as one standard deviation about the mean.

System Response Time - The time interval from a step change in pollutant concentration at the input to the monitoring system to the time at which 95% of the corresponding value is reached as displayed on the system data recorder.

Output Noise - Spontaneous, short duration deviations in the analyser output, about the mean output, which are not caused by input concentration changes. Noise is determined as the standard deviation about the mean expressed as a percentage of full scale.

Zero Drift - The change in the continuous monitoring system output over a stated period of time of normal continuous operation when the pollutant concentration at the time of the measurement is zero.

Span Drift - The change in the continuous monitoring system output over a stated period of normal continuous operation when the pollutant concentration at the time of measurement is the same known upscale value.

Interference Equivalent - Positive or negative response caused by a substance other than the one being measured.

Operational Period - A minimum period of time over which a measurement system is expected to operate within certain performance specifications without unscheduled maintenance.

4.2 PERFORMANCE TEST PROCEDURES

The field performance test procedures, which were based on those presented for monitors of SO_2 and NO_x from stationary sources (Federal Register, Volume 40, Number 194 - Monday, October 6, 1975), are presented below.

Procedures for precision, output noise, and interference equivalent are presented in Section 5.1 of this report.

The field performance test data for the five carbon monoxide instruments were selected from periods of representative performance. Periods during which an instrument was known to be malfunctioning were avoided.

Relative Accuracy

For continuous monitoring systems employing extractive sampling the sample for the modified method 10 instrument (MODIR), whenever possible, shall use the same sample delivery system as the continuous monitor being evaluated. In the case of a non-extractive system, or where the sampling system for the continuous monitor cannot be used, the probe for the reference method analysers and the probe for the continuous monitor should be at adjacent locations in the duct. In the case of an in-situ cross-stack monitor the reference method probe should be centrally located in the duct as close to the measurement path of the continuous monitors as possible.

Determine the average reference method response during one 15 minute segment each hour for 9 hours. For each of these 9 reference test points, determine the average pollutant concentration reported by the continuous monitor being evaluated. These averages shall be concurrent with the reference method time intervals. For each of these 9 test intervals, determine the difference for each pair by subtracting the reference method concentration (15 minute average) from monitoring system concentration (15 minute average). Using these data, compute the mean difference and the 95% confidence interval of the differences using equations 1 and 2 shown below. Relative accuracy is reported as the sum of the absolute value of the mean difference and the 95% confidence interval of the differences expressed as a percentage of the mean reference method value.

Equations

1. The mean difference of a data set is calculated as follows:

$$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} Xi$$

where:

Xi = Absolute value of the measurements
Σ = Sum of all individual values
$\bar{X}$ = Mean value, and
n = Number of data points

2. The 95% confidence interval (two-sided) is calculated as follows:

$$C.I._{95} = \frac{t_{.975}}{n\sqrt{n-1}} \sqrt{n(\Sigma s_i^2) - (\Sigma s_i)^2}$$

where:

Σs_i = Sum of all data points
$t_{.975} = t_{1-\alpha/2}$, and
$C.I._{95}$ = 95% confidence interval estimate of the average mean value

Values For $t_{.975}$

n	$t_{.975}$
2	12.706
3	4.303
4	3.182
5	2.776
6	2.571
7	2.447
8	2.365
9	2.306
10	2.262
11	2.228
12	2.201
13	2.179
14	2.160

Response time

Introduce zero gas into the continuous monitoring system sampling interface or as close to the sampling interface as possible. When the system output reading has stabilized, switch quickly to a known concentration of pollutant gas. Record the time from concentration switching to 95 percent of final stable response. For non-extractive monitors, the highest available calibration gas concentration shall be switched into and out of the sample path and response times recorded. Perform this test sequence three (3) times. Report the mean of the three upscale test times and the mean of the three downscale test times. The two average times should not differ by more than 15 percent of the slower time. Report the slower time as the system response time.

Zero Drift (2 Hour)

Record the values given by the introduction of zero gas at two hour intervals until 15 data points are obtained. For non-extractive systems, the zero value may be determined by mechanically producing a zero condition that provides a system check on analyzer internal mirrors, electr[illegible] circuitry, radiation source and detector assembly. The two hour p[illegible]s over which the measurements are taken need not be consecutive b[illegible]ays may not overlap.

Using this data, calculate the differences between consecutive two hour readings expressed in ppm. Calculate the mean difference and the 95% confidence interval using equations 1 and 2 on page 14. The two hour zero drift is reported as the sum of the absolute mean value and the 95% confidence interval expressed as a percentage of span.

Zero Drift (24 Hour)

Record the zero concentration values every 24 hours during a 168 hour operational field test period. Using the zero values obtained calculate the difference between the zero point after adjustment (if any) and the zero value 24 hours later prior to any adjustment. Calculate the mean value of these points and the 95% confidence interval using equations 1 and 2 on the previous page. Report the zero drift (sum of the absolute mean value and the confidence interval) as a percentage of span.

Calibration Drift (24 Hour)

Record the calibration values measured every 24 hours during a 168 hour operational test period. Using the calibration values obtained calculate the difference between the calibration value after zero and calibration adjustments and the value obtained 24 hours later, after zero but before calibration adjustment. Calculate the mean values of these points and the 95% confidence interval using equations 1 and 2 on the previous page. Report the calibration drift (sum of the absolute mean value and the confidence interval) as a percentage of span.

Operational Test Period

During the 168 hour operational test period, the continuous monitoring system shall not require any corrective maintenance, repair, replacement or adjustment other than that specified, as required by the manufacturer and expected in a one-week period. If the monitoring system performs as above and remains within performance specifications, the test is considered successful.

SECTION 4

DESCRIPTION OF INSTRUMENTATION

4.1 ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC. STACK GAS ANALYZER - MODEL 4000

The Environmental Research and Technology Stack Gas Analyser Model 4000 is a multi-component in-situ continuous monitor that measures concentrations of component gases based on absorption of infrared energy. For this application, the instrument measured carbon monoxide, although it has the capability for simultaneous measurement of NO, SO_2, CO and CO_2.

The instrument consists of an infrared source and a detector which are mounted on opposite walls of a stack or duct. The concentration of the component gas is based on the attenuation of infrared energy by the gas as the IR beam travels across the duct.

The intensity of this IR beam is attenuated, however, by factors other than CO in its travel across the duct. Variations in particulate concentration, for example, introduce source intensity fluctuations at the detector. These intensity fluctuations, which are independent of CO concentrations, must not be detected as CO. The design of the ERT instrument continuously compensates for these intensity fluctuations by using a gas correlation technique that makes measurement relatively independent of source intensity. This is accomplished through a two phase analysis cycle that alternates between measurement of the source and an internal reference source. Variations in stack temperature affecting concentration measurements are continuously compensated for by a temperature sensor and the instrument's electronics.

Routine calibration of the instrument is controlled by a switch located at the instrument's recorder which directs a calibration IR beam through a reference cell containing CO in the detector. This should produce a pre-established response on the instrument's recorder.

The continuous recorder containing the switches for calibration is remotely located and connected to the detector on the stack or duct by an umbilical cable.

The manufacturer's specifications for the ERT instrument are presented in Table 7.

4.2 ECOLYZER (MODEL 1100), ENERGETICS SCIENCE, INC.

The Ecolyzer senses levels of carbon monoxide by means of an electrochemical detector which produces an electrical current proportional to the concentration of CO in the input sample. This current is produced within the detector by the electro-oxidation of carbon monoxide causing a current flow between two electrodes. The current causes a deflection on a milliammeter indicating the concentration of carbon monoxide relative to calibration. An output is also provided for a continuous recorder. The manufacturers specifications for the Ecolyzer are reproduced in Table 8.

Figure 1 is a flow diagram showing the major components in the instrument. The internal sample pump with associated valve and flow meter maintains constant flow through the instrument which is necessary for accurate response. When using an external sample pump, a bypass must be provided to prevent pressure and flow variation at the instrument.

The following sample conditioning steps were recommended by the manufacturer for the field application at the Sun Oil site:

- Cool the emission gas sample to ambient temperature if possible, but at least down to 100°F.
- Reduce the sample gas pressure to ambient pressure if possible, but at least down to 2 inches of water above ambient.

TABLE 7. MANUFACTURER'S SPECIFICATIONS

ERT STACK GAS ANALYZER

Range of Operating Conditions	
Stack Gas Temperature	20°F - 600°F
Source Attenuation (due to combination of stack opacity and window transmission)	0 - 80%
Ambient Temperature Range	-20°F - +105°F
Humidity	0 - 100% relative
Power Requirements	Sensor - 500 Watts at 110 Volts ± 20%, 60 Hz Source - 2000 Watts at 220 Volts ± 20%, 60 Hz
Vibration	No special vibration isolation required.
All Weather Enclosure Provided	
Data Interface	Analog Output - 0 to 10 VDC Status Lights - Power On Window DIRTY Remote Control - Span Calibration
Gas Concentration Ranges	
CO - 500 ppm minimum full scale, or greater as required	
Accuracy of Initial Calibration	
CO ± 25 ppm or ± 5% of indicated value, whichever is greater	
Maximum Drift (24 hour)	
CO - Zero ± 5% ppm	Span ± 25 ppm
Weight and Size	
Sensor 23-1/2" x 27-1/2"x 11-5/8"	112 lbs
Source 19" x 19" x 18"	66 lbs
*11-1/2" with handles and flange	
Window and Source Purge	
Where required, for example for positive pressure applications, windows and source purge systems can be provided.	

TABLE 8. CAPABILITIES AND CHARACTERISTICS

ECOLYZER

Item	Characteristics
Power Requirements	
AC	95-130 volts, 50/60 Hz
Battery	One (1) Mercury cell 1.35V Four (4) C size nickel/cadmium 1.25V each
Minimum Detectable Sensitivity	0.5 ppm (0-50 ppm scale)
Readout	Meter (100 divisions full scale)
Range	0-50, 0-100, 0-500 ppm; (0-1000, 0-2000 ppm and dual range option)
Sensor	Electrochemical
Sensor Life	One (1) year in use
Circuitry	Solid State
Operating Temperature Range	Internal temperature controlled (optional) for 0 to 125°F ambient compensation
Temperature Compensation	Built-in thermistor compensation
Calibration	As required
Rise Time	Approximately 90 seconds
Fall Time	Approximately 90 seconds
Zero Drift	Less that ± 0.5% per day
Span Drift	Less than ± 1.0% per day
Accuracy	± 1.0% (full scale)
Noise	± 0.2% (full scale)
Linearity	± 1.0% (full scale)
Relative Humidity Range	5 to 95%

FIGURE 1. 3000 Series Ecolyzer, Flow Diagram

- Remove water condensate in a trap. Ideally, the sample entering the Ecolyser should have a relative humidity of about 80%.
- Insure that there is a particulate filter in the gas sample line.
- Insure that the Ecolyser humidity adjustment system is used according to instructions.

4.3 BECKMAN AIR QUALITY CHROMATOGRAPH (MODEL 6800)

The Beckman Chromatograph is a multi-component continuous monitor employing column separation of gaseous components and detection by flame ionization detector (FID). The instrument is totally automated and can be programmed to accommodate a wide variety of applications. Internal automatic functions are performed by solenoid actuated slider valves controlled by a solid state timer.

The basic three component unit used in this program was capable of measuring total hydrocarbons, methane and carbon monoxide. After column separation, a catalytic methanator is used to convert carbon monoxide to methane permitting detection by the flame ionization detector. The Model 6800 is designed as an ambient monitor with a maximum sensitivity of 0-300 ppm, and it was necessary to decrease the size of the sample loop to prevent saturation of the detector in the 0-1000 ppm CO range required for stack gas analysis. The instrument was programmed to perform one analysis every five minutes (12 analysis cycles each hour). The manufacturer's specifications are reproduced in Table 9.

4.4 BECKMAN MODEL 865 NON-DISPERSIVE INFRARED ANALYZER

The Model 865 infrared analyser continuously measures levels of various infrared absorbing gases based on the differential absorption of infrared energy between a flowing sample cell and a sealed referenced cell. The concentration of the component gas is then proportional to the absorption of infrared energy by that gas in the sample cell relative to

TABLE 9. SPECIFICATIONS

BECKMAN AIR QUALITY CHROMATOGRAPH

Measurements - Standard three-component analysis determines carbon monoxide, methane, and total hydrocarbons. Optional five-component analysis includes determinations of ethylene and acetylene.

Operation - Automatic, unattended, repetitive analysis at selectable rate of 4, 6, or 12 analyses per hour for three-component system; 4 or 6 analyses per hour for five-component system. Automatic readjustment of electronic zero during each analysis cycle. Automatic daily analysis of calibration standard gas available as an option for three-component system only.

Ranges - Individually selectable, automatically actuated, ranges for each component. Maximum sensitivity, 1 ppm to 700 ppm full scale.

Sample - Ambient air. Integral pump provides sample flow rate of 5 liters per minute at standard temperature and pressure.

Precision - ± 0.5% of full scale or 0.05 ppm, whichever is greater.

Linearity - 1% of full scale.

Zero Drift - Automatic zero adjustment during each analysis cycle compensates for zero drift.

Interference From Other Gases - None

Automatic Timing - Precision digital timing provides one-second resolution for all time-related analysis functions.

Output Signals

1. Individual 0 to 5 volts d.c. outputs for each pollutant for trend recording, computer, telemetry, or other data-acquisition equipment. Output impedance = 0.
2. Zero to 100 millivolts d.c. output for chromatogram and/or bar-graph readout on potentiometric recorder. This output available at both a rear-panel connector for a permanent recorder, and at a front-panel jack for temporary connection of a test recorder.

Ambient Temperatures - 35°F to 120°F, 95% relative humidity.

Gases Required - Hydrogen, 70 cc/min at 30 to 150 psig; air, 150 cc/min at 30 to 150 psig.

Dimensions - 17 inches wide x 40 inches high x 20 inches deep.

Shipping Weight - 250 pounds.

Power - 107 to 127 volts a.c.; 50/60 Hz, 500 watts.

the reference cell. The instrument's detector has two compartments separated by a diaphram. Each compartment is filled with the component gas to be sampled. The infrared energy passing through the cells excites the molecules in each detector compartment. The difference in excitation between the sample and reference side of the detector causes distention in the diaphram between the detector compartments. This distention causes a capacitance change, which is equivalent to the component concentration in the sample cell, and is amplified for output. The practical range of the instrument is a function of sample cell length. The Beckman 865 used in the program employed a 13-1/2 inch cell accommodating the 0-1000 ppm CO range. The manufacturer's specifications are reproduced in Table 10.

4.5 HORIBA NON-DISPERSIVE INFRARED ANALYZER (MODEL AIA-2 AND AIA-21AS)

The original Horiba NDIR (Model AIA-2) selected for this program was replaced during the field program by a newer model AIA-21AS. Both Horiba instruments are infrared analysers that measure levels of infrared absorbing gases based on the differential absorption of infrared energy between the flowing sample cell and a sealed reference cell. The concentration of the specific input gas is then proportional to the attenuation of infrared energy by the gas in the sample cell. The basic operating principle is the same as described for the Beckman Model 865 NDIR.

Both Horiba instruments used a 500 mm cell that measured carbon monoxide on the 0-1000 ppm range. The Horiba Model AIA-21AS incorporated optical filters and a new detector designed to reduce interference from water and CO_2. The manufacturer's specifications for the AIA-2 and AIA-21AS are reproduced in Tables 11 and 12.

TABLE 10. SPECIFICATIONS

BECKMAN MODEL 865 NON-DISPERSIVE INFRARED ANALYZER

Accuracy - 1% of full scale.

Span Drift* - ± 1% of full scale in 24 hours.

Zero Drift* - ± 1% of full scale in 24 hours.

Ambient Temperature Range - 30°F to 120°F (-1°C to 49°C)

Line Voltage - 115 ± 15 volts rms.

Line Frequency - 50/60 ± 0.5 Hz

Power Consumption - 400 watts.

Electronic Response Time (0 to 90% of full scale)

Switch selection of fast or slow response.
FAST switch position provides 0.5-second response (optional 1-second response obtainable by clipping jumpers).
SLOW switch position provides 7.5-second response.

Output

Standard (Potentiometric)
0 to 10, 0 to 100 millivolts, 0 to 1, 0 to 5 volts d.c. (field selectable).

Optional (Current)
4 to 20 and 10 to 50 milliamperes, d.c. (field selectable)
or, Linearized (Potentiometric)
0 to 10, 0 to 100 millivolts, 0 to 1, 0 to 5 volts d.c. (field selectable)

*Performance specifications based on ambient temperature shifts of less than 20 Fahrenheit degrees (11 Centigrade degrees) at a maximum rate of 20 Fahrenheit degrees (11 Centigrade degrees) per hour.

TABLE II. SPECIFICATIONS

HORIBA NON-DISPERSIVE INFRARED ANALYZER MODEL AIA-2

Measuring Method - Infrared analyzer, non-dispersive method, positive filter, double light sources, deflection type.

Accuracy - ± 1%

Drift - ± 1% full scale for 8 hours

Speed of Response - 90% electronic response in 0.5 seconds.

Sensitivity - 0.5% of full scale

Typical Measuring Ranges -

CO (carbon monoxide)
0-1%, 0-3%, 0-5%, 0-10%, 0-12%
0-1000 ppm, 0-250 ppm

All measurement ranges for any one component can be incorporated within a multiple range analyser but means of an electrical dual or triple range selector or a stacked cell configuration. Flowing reference and filter cells also available.

Output

0-10 mv and 0-100 mv D.C. for recorder and
0-1 V and 0-5 V input to Data Acquisition System.

Ambient Temperature Range - 32°F to 105°F

Power Requirement - 115 V A.C. (60 Hz) or 230 V A.C. (50 Hz) 250 VA

Weight - Analyser Section: approx. 40 lbs. (18 Kg)
Amplifier Section: approx. 28 lbs. (12.6 Kg)

TABLE 12. SPECIFICATIONS

HORIBA NON-DISPERSIVE INFRARED ANALYZER MODEL AIA-21AS

Measuring Method - NDIR, positive filter, dual source reflection type.

Repeatability - ± 1% of full scale

Sensitivity - 0.5 of full scale

Speed of Response - 90% electronic response in 0.5* seconds.

* A slower response (up to 2 seconds) is required in some applications)

Drift - Zero Drift: 1% of full scale in 8 hours
Span Drift: 1% of full scale in 8 hours

Outputs - 0-1 ma for remote meter readout
0-10 and 0-100 millivolts for pot. recorder
0-1 and 0-5 volts for data acquisition system

(Range indentification outputs are also available on multi-range application.)

Ambient Temperature Range - 0 to 40°C (32 to 105°F)

Sample Temperature Range - 0 to 40°C (32 to 105°F)

Recommended Sample Flow - 1 to 10 liters per minute (0.1 to 21 CFH)

Sample Cell Temperature - 55°C (131°F) regulated

Power Requirement - 115 VAC at 60 Hz

Weight/Unit (approx.) - Analyzer Section (Typical): Version 1 7.7 Kgs. (17 lbs)
Electronics Module Section (Typical):
1-pack 10.3 Kgs (23 lbs)

Sample Connections - 1/8" N.P.T. (inlet and outlet)

SECTION 5

LABORATORY PERFORMANCE EVALUATION

5.1 DESCRIPTION OF TEST PROCEDURES

The laboratory evaluation consisted of a series of performance tests on each instrument. The parameters tested included:

- response characteristics (calibration)
- precision
- noise
- response times (rise and fall)
- H_2O and CO_2 interference
- flow and temperature variation
- zero and span drift

Federal Register Volume 40, Number 33, February 18, 1975, Subpart B, "Procedures for Testing Performance Characteristics of Automated Methods", was used as the basis for the laboratory evaluation tests.

Gas standards used for calibrations and all performance tests were Scott close tolerance cylinder mixtures of carbon monoxide in nitrogen. The mixtures were analyzed against NBS standard reference mixtures containing 100, 500 and 1000 ppm CO. Zero gas used was Scott 99.99% pure nitrogen. Gas for the CO_2 interference tests was a Scott blend of 15% CO_2 in nitrogen.

5.1.1 Response Characteristics (Calibration)

Calibration procedures consisted of introducing several CO calibration gases and nitrogen zero gas into each instrument being tested. Calibration curves were constructed by plotting the instrument responses on the ordinate against the CO concentrations on the abscissa.

5.1.2 Precision (Repeatability)

Precision is the standard deviation about the mean of repeated

measurement of the same gas concentration. This value is expressed in concentration units. During the test, measurement of the selected gas is interrupted alternately by the introduction of a higher and a lower gas concentration. Six stable readings of the selected gas are obtained after each injection of the higher or lower standard. These values are then entered into the following equation for precision.

$$P = \sqrt{\frac{1}{5}\left[\sum_{i=1}^{6} P_i^2 - \frac{1}{6}\left(\sum_{i=1}^{6} P_i\right)^2\right]}$$

Where: P = Precision

P_i = Instrument Response (ppm) for the i^{th} measurement

5.1.3 Output Noise

Instrument noise is short-term variations in instrument output not caused by changes in input concentration. This value is expressed in concentration units as the standard deviation about the mean. The recommended procedure is to test for noise using zero and 80% of full scale gas standards.

The test procedure calls for allowing the instrument to stabilize on the gas standard and then take 25 readings within a 60 minute period using a digital voltmeter. These voltages are converted to concentration units and entered into the equation for noise.

$$N = \sqrt{\frac{1}{24}\left[\sum_{i=1}^{25} (ri)^2 - \frac{1}{25}\left(\sum_{i=1}^{25} ri\right)^2\right]}$$

Where: N = Instrument Noise (ppm)

ri = Instrument Response for the i^{th} reading (ppm)

5.1.4 Response Times (Rise and Fall)

Rise Time: Rise time is the time interval between initial instrument response and 95% of the final response after a step increase in input gas concentration. The test procedure involves changing the input from zero gas to a high range span gas. Rise time was calculated from the recorder chart which was run at high speed for this test.

Fall Time: Fall time is the time difference between initial response and 95% of final response after a step decrease in input gas concentration. During this test, the input was changed from a high range span gas to nitrogen zero gas. Times were also measured on the recorder chart.

Figure 2 illustrates the procedure used for measurement of response times.

5.1.5 CO_2 and H_2O Interference

CO_2: CO_2 interference was determined using a Scott blend of 15% CO_2 in nitrogen. The procedure used was to first allow the instrument to stabilize on nitrogen zero gas. The response to the introduction of the 15% CO_2 is then expressed in parts per million as an equivalent CO concentration.

H_2O: H_2O interference was determined by the addition of 10% water vapor while the instrument was sampling nitrogen zero gas. The response to the added water vapor is expressed in parts per million as an equivalent CO concentration. Water vapor was added by passing nitrogen through a flask containing distilled water. The flask was heated sufficiently to introduce 10% water vapor into the flowing sample. This water vapor generator was calibrated using EPA Method 4.

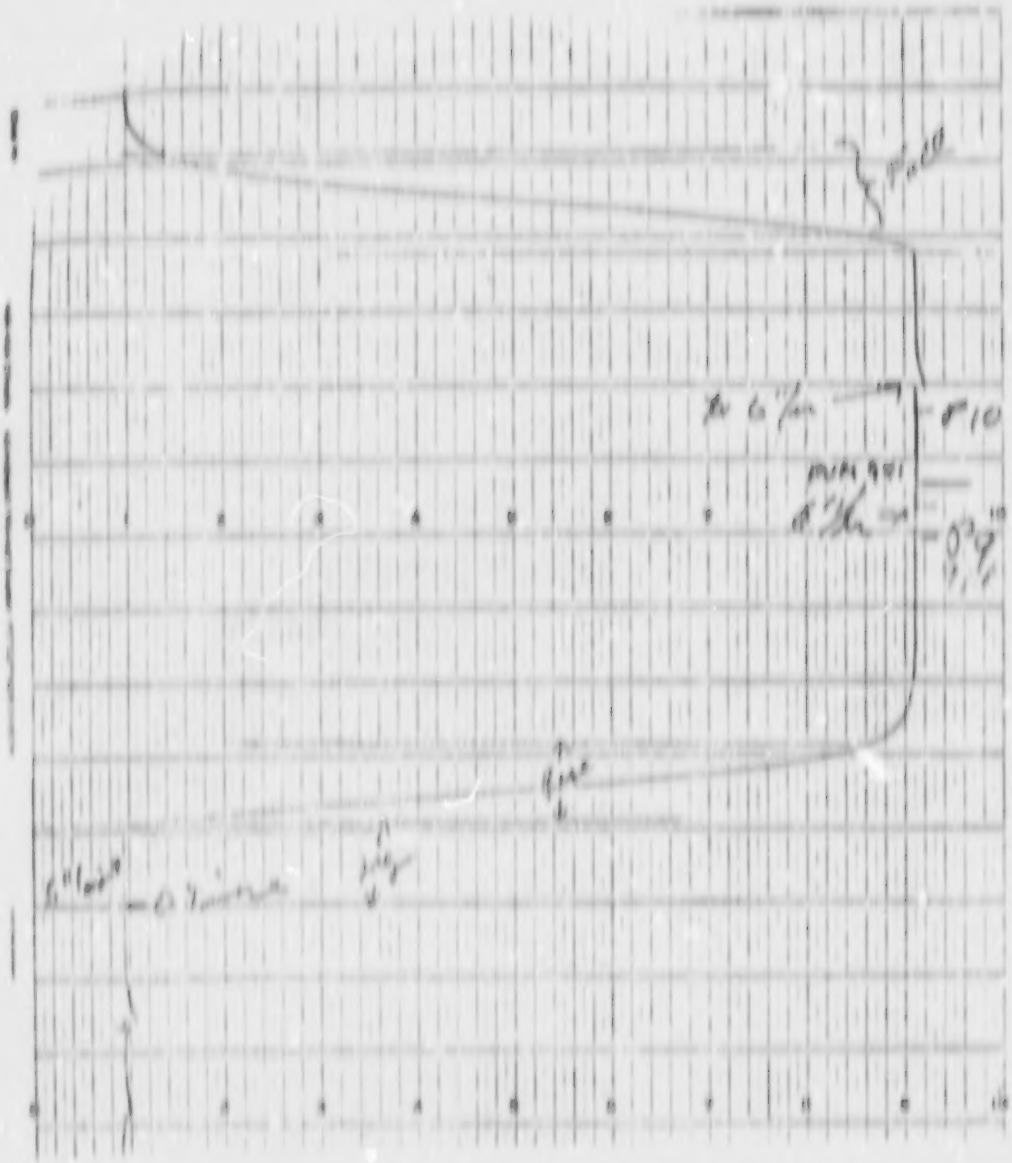

FIGURE 2 RESPONSE TIMES (RISE AND FALL)

3.1.6 Variations Due To Changes In Temperature And Flow Rate

Variations in instrument output caused by short term changes in ambient temperature were measured using nitrogen zero, 161 and 897 ppm CO span gases. The test procedure involved recording stable responses to the three gases at a given temperature then changing the temperature and again recording the stabilized responses. These tests were performed in February and the temperature was varied by regulating heat and opening two large garage doors.

The effects of variation in input flow rate were tested using the 807 ppm CO standard. During the test, the input flow rate was varied from 0-5 liters/minute and responses were monitored with a digital voltmeter. Flows were monitored with a calibrated rotameter.

3.1.7 Zero and Span Drift

12 Hour Continuous Zero Drift: This test involved sampling zero air for 12 consecutive hours. The recorder chart was then examined for the minimum and maximum responses. The maximum minus the minimum response equals the zero drift expressed as parts per million CO.

6 and 24 Hour Zero Drift: For this test the responses to the input of nitrogen zero gas were recorded and entered into the equation $ZD = S_n - S_{n-1}$ for the n^{th} test period. This is expressed in parts per million.

Span Drift: Span drifts were calculated by recording the instrument response at the beginning and end of the time interval being tested. The chart responses are entered into the equation:

$$\text{Span Drift} = \frac{S_n - S_{n-1}}{100}$$

The results are presented as a percent of full scale and as equivalent parts per million.

5.2 LABORATORY TEST RESULTS

5.2.1 Environmental Research & Technology, Inc. Stack Gas Analyzer-Model A900

Calibration and performance testing of the ERT monitor was conducted at the ERT Laboratories in Concord, Massachusetts on September 15 and October 15, 1975. The second calibration was necessary because the instrument used in the first tests was not the one furnished for this project and the gases used were not comparable to those used on the other instruments. A summary of these test results is shown in Table 13.

Calibration

Calibration of the ERT instrument involves mounting the instrument on a 16 foot test cell that can be evacuated and heated. The equivalent stack concentration is proportional to the ratio of the test cell length to the stack path length.

In the first test series, each calibration point was prepared by adding gas from a cylinder of 3200 ppm CO to a pre-calculated pressure into the evacuated cell. Nitrogen was then added to bring the cell to atmospheric pressure. The concentration of the test cell is a function of the partial pressure at which the calibration gas is introduced.

The following data were recorded:

Equivalent Stack CO Concentration	Interference Gas	Millivolt Output	Cell Temperature (°F)
1100.5	None	77.5	260
680.8	None	42.0	315
282.7	None	20.5	345
0.0	None	1.0	345
0.0	48.22% CO_2 25% H_2O	5.0	345

The second calibration series was made at ERT after the instrument furnished for this project was available. Three Scott standard CO mixtures used for the calibration of the other instruments on this project were transported to ERT. Their concentrations were 100, 321, and 496 ppm.

TABLE 13 PERFORMANCE TEST SUMMARY
ERT MODEL 4000

Range: 0-1000 ppm

Precision: Not Tested

Noise: (Using Internal Cal Mode) 35.5 ppm

Response Times: Not Tested

Interference: 15% CO_2 - 20 ppm

15% CO + 12% H_2O - 25 ppm

Zero and Span Drift: Not Tested

The test cell at ERT was evacuated and filled to atmospheric pressure with each of the Scott gases. The following are the results of the calibration. Figure 3 shows the calibration curve.

Cylinder Concentration	Equivalent Stack Concentration	Millivolt Output	Cell Temperature (°F)
100 ppm CO	195.8 ppm CO	19.5	400
321 ppm CO	495.7 ppm CO	53	400
496 ppm CO	774.5 ppm CO	83	400

Precision

Due to the special nature of the test cell procedure, tests for precision were not practical for the ERT instrument.

Noise

The test for instrument noise was performed on January 22, 1976 while the instrument was at the Sun Oil Company site. The internal calibration mode was used as the source and readings were taken with a digital voltmeter. The test data are shown in Table 14.

Response Times

Response times were not measured during the ERT laboratory checkout.

Interference

Interference tests for H_2O and CO_2 were performed during the ERT laboratory checkout. The instrument's response to 15% CO_2 in N_2 was first recorded, then sufficient water to yield 12% moisture was injected into the heated cell in addition to the 15% CO_2. The responses were as follows:

Cell Concentration	Equiv. Stack Concentration	Response (mv)	Equivalent ppm CO
N_2 (zero gas)	0	0	0
15% CO_2 in N_2	29.4% CO_2	1	20
15% CO_2 + 12% H_2O	29.4% CO_2 + 24% H_2O	2.5	25

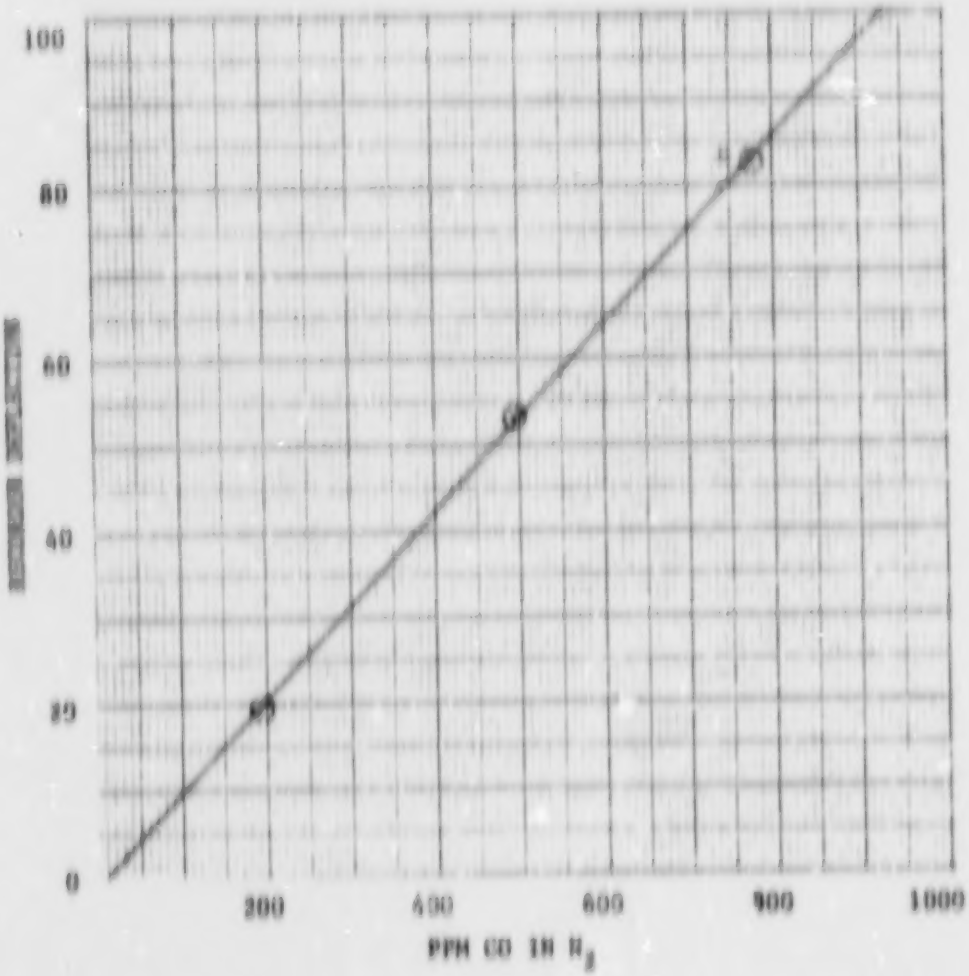

FIGURE 3 BRI MODEL 4000 CALIBRATION CURVE

TABLE 14 NOISE TEST DATA

Applicant _____ Date 12/2/76

Test No _____

Analyzer ENT - Model 1000 Range 0 - 1000 PPM

READING NUMBER (I)	TIME	85% of URL		80% of URL	
		DM READING	Y_i ppm	DM READING	Y_i ppm
1	2			7.45	7.45
2	4			7.66	7.66
3	6			7.31	7.31
4	8			6.95	6.95
5	10			7.57	7.57
6	12			7.60	7.60
7	14			7.02	7.02
8	16			7.73	7.73
9	18			7.36	7.36
10	20			7.18	7.18
11	22			7.62	7.62
12	24			7.51	7.51
13	26			7.58	7.58
14	28			7.31	7.31
15	30			7.24	7.24
16	32			7.29	7.29
17	34			7.07	7.07
18	36			8.09	8.09
19	38			7.57	7.57
20	40			8.20	8.20
21	42			7.66	7.66
22	44			7.18	7.18
23	46			8.21	8.21
24	48			8.07	8.07
25	50			7.30	7.30
$\sum_{i=1}^{n} Y_i$					189.67
$\sum_{i=1}^{n} Y_i^2$					1426.4226
n			4		$\bar{Y}_{80} = 35.5$

Temperature Variation

Tests for temperature variation were not performed on the ERT during its initial checkout at the ERT laboratories.

Flow Variation

Laboratory tests for flow variation effects could not be conducted with the static test cell used for the ERT laboratory testing.

Zero and Span Drift

Laboratory tests for instrument drift were not conducted on the ERT instrument.

5.2.2 Energetics Science Inc. Ecolyzer - Model 3100 (Serial No. 31113)

Performance tests on the Ecolyzer were conducted both before and after the field program. Some of the tests planned for after the field program were omitted due to the deterioration of the detector cell that occurred during the field program. Figure 4 illustrates the change in response after the detector deterioration. Although the initial response to the input gas was good, it immediately dropped off, after which it took in excess of 1 hour to stabilize. During this stabilization, the response slowly drifted upscale toward the final response.

A summary of the laboratory tests on the Ecolyzer is presented in Table 15.

Calibration

Calibration performed on December 1, 1975 is shown below. the calibration curve is shown in Figure 5.

CALIBRATION POINTS 12/1/75

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
100	10.5
321	34
496	49.5
650	65
807	79.7
925	87

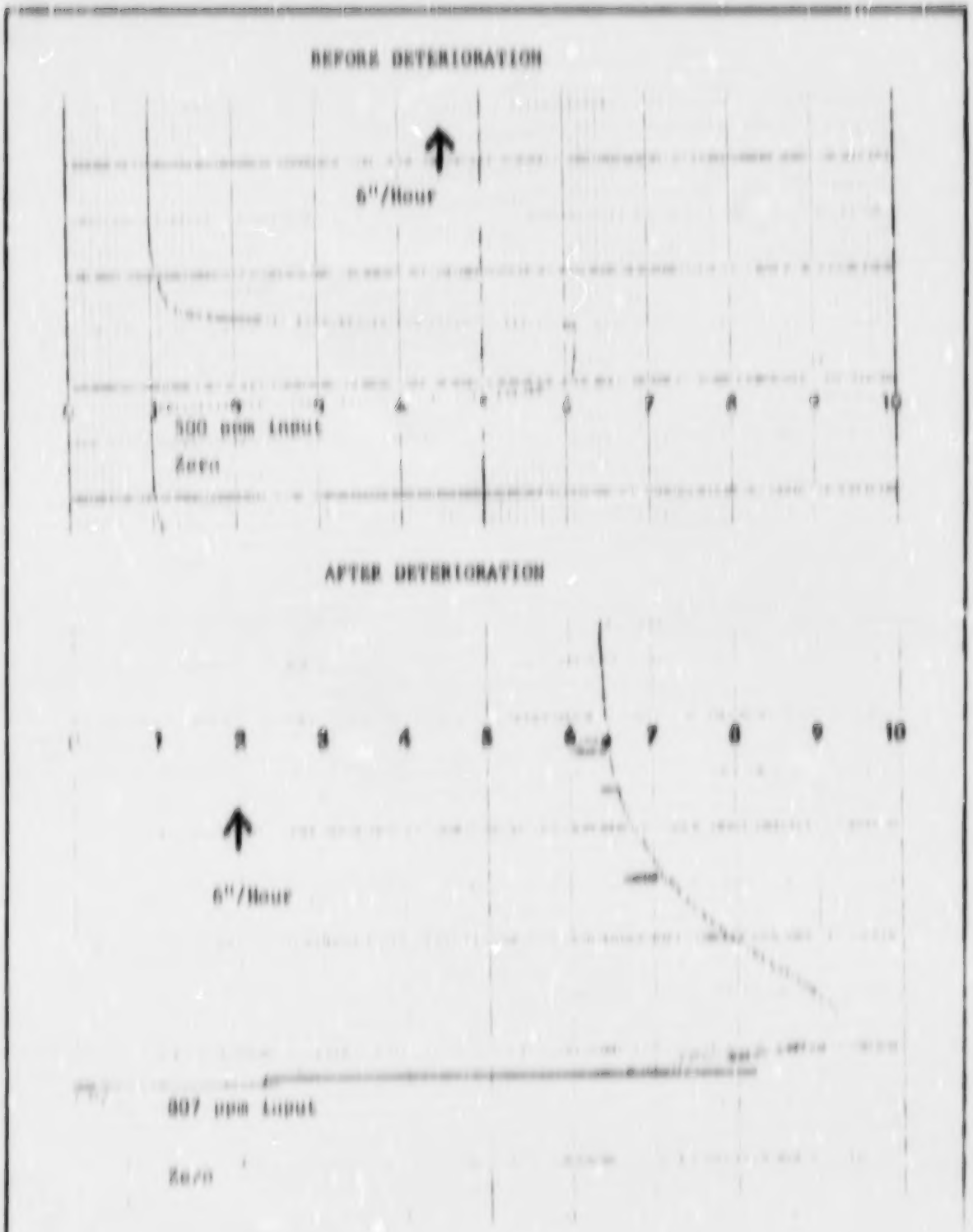

FIGURE 4 ECOLYZER RESPONSE CHANGES (BEFORE AND AFTER DETERIORATION)

TABLE 15. PERFORMANCE TEST SUMMARY

ECOLYZER

Range: 0-1000 ppm CO

Precision: (163 ppm) 4.32 ppm

Noise: Nitrogen Zero = 0.46 ppm
807 ppm CO = 1.6 ppm

Response Times: Rise = 86 seconds
Fall = 83 seconds

Interference: CO_2 = 0 ppm

Zero Drift: (% of Full Scale)
12 hour continuous = 0.6*
24 hour = 0.2*

24 Hour Span Drift: (% of Full Scale)
163 ppm = 0.4*
807 ppm = 0.4

*Average

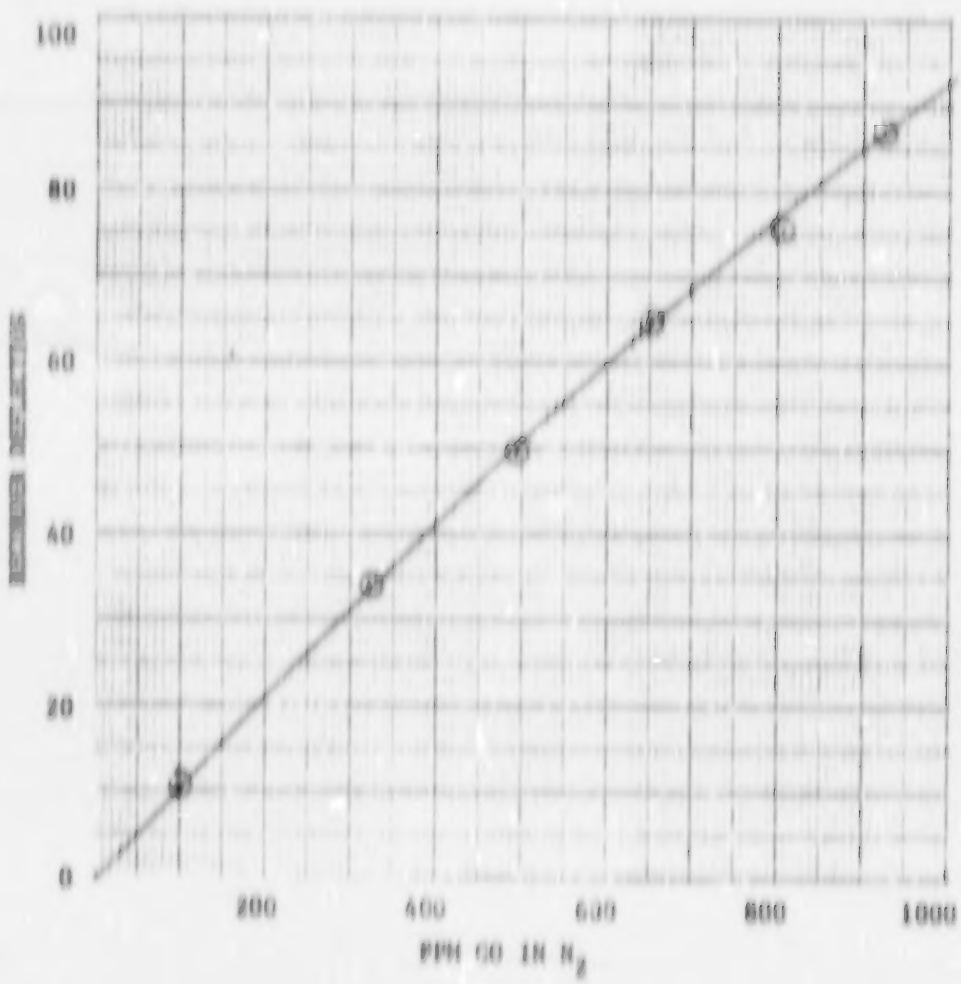

FIGURE 5 DRAGER CALIBRATION CURVE

Precision

The test for precision was conducted on February 12 using the 163 ppm calibration standard. The test results are shown below. Precision tests using a higher range gas planned for after the field program were omitted due to the extended response times.

PRECISION TEST 2/12/76

	Calibration Standard (ppm)	Instrument Response (ppm)
F_1	163	163
F_2	163	163
F_3	163	168
F_4	163	163
F_5	163	173
F_6	163	170

F_{163} = 4.32 ppm

Noise

Tests for instrument noise were conducted using nitrogen zero gas and the 807 ppm CO standard. The results are shown on Table 16.

Response Time

The rise and fall times for the Analyser using the 1060 ppm CO standard were 86 and 83 seconds, respectively. This test was performed in October 1975 while the detector was in good condition.

Interference

CO_2 interference was tested on the 0-1000 ppm range using 15% CO_2 in nitrogen. The input changed from nitrogen to 15% CO_2 in nitrogen produced no change in instrument response.

Temperature Variation

Effects of temperature variation on instrument response was tested using zero, 163 ppm and 807 ppm calibration standards.

TABLE 16. NOISE TEST DATA

Applicant _____ Date _____

Test No _____

Analyzer Enterprise Range 0 - 1000 ppm

READING NUMBER (i)	TIME	95% of URL		80% of URL	
		DM READING	x_i ppm	DM READING	x_i ppm
1	0	29	0	796	807
2	4	028	-1	794	787
3	6	28	-1	785	808
4	8	28	-1	793	806
5	10	29	0	794	807
6	12	28	-1	785	805
7	14	28	-1	796	809
8	16	29	0	796	809
9	18	29	0	787	710
10	20	29	0	797	810
11	22	29	0	797	810
12	24	29	0	797	810
13	26	29	0	796	809
14	28	29	0	797	810
15	30	29	0	796	809
16	32	28	-1	796	809
17	34	29	0	796	809
18	36	29	0	797	810
19	38	29	0	797	810
20	40	29	0	797	810
21	42	29	0	798	811
22	44	28	-1	797	810
23	46	29	0	798	811
24	48	29	0	799	812
25	50	29	0	795	808
$\sum_{i=1}^{n} x_i$			7		20234
$\sum_{i=1}^{n} x_i^2$			7		1637465
$\bar{x}$			$\bar{x}$ = 0.46		$\bar{x}_{95}$ = 1.6

2/11/76

	Time	Temperature	Response
Zero Gas	0900	70°	9.0 ct. units
	1500	60	9.5
			0.5 ct. units = 5.7 ppm
163 ppm	0900	70	15.1 ct. units
	1500	60	13.7
			1.4 ct. units = 16 ppm
807 ppm	0900	70	73 ct. units
	1500	60	70.8
			2.2 ct. units = 25.1 ppm

Flow Variation

Variations in input flow rate, within the manufacturer's recommended range, had negligible effects on instrument output.

Zero and Span Drift

Tests for instrument drift are presented below. These tests include 12 hour and 24 hour zero drift and mid and high range span drifts.

12 Hour Continuous Zero Drift

10/10/75	Maximum	10.3 chart units
	Minimum	9.9
	12 Hr. Drift	0.4 chart units = 4.6 ppm
2/11/76	Maximum	10.0 chart units
	Minimum	9.0
	12 Hr. Drift	1.0 chart units = 11.4 ppm
2/12/76	Maximum	10.2 chart units
	Minimum	9.7
	12 Hr. Drift	0.5 chart units = 5.7 ppm

24 Hour Zero Drift

		Response (% of full scale)			
Date	Temp.	Z_n	Z_{n-1}	Drift (ΔZ)	Equiv. ppm
2/11-12	70	8.3	8.5	-0.3	3.4
2/12-13	60	8.2	8.3	-0.1	1.1

Span Drift

Gas Standard 163 ppm

Date	Temp.	Response (% of full scale) R_n	R_{n-1}	Drift (ΔR)	Equiv. ppm
24 hour					
2/11-12	70	14.1	14.7	-0.6	6.9
2/12-13	60	13.9	14.1	-0.2	2.3

Gas Standard 807 ppm

Date	Temp.	Response (% of full scale) R_n	R_{n-1}	Drift (ΔR)	Equiv. ppm
24 hour					
2/11-12	70	73.0	73.6	0.4	4.6

3.2.1 Beckman Air Quality Chromatograph (Model 6800) (Serial No. 1000119)

Performance tests for the Beckman 6800 were conducted both before and after the field program. A summary of the laboratory performance tests is shown in Table 17. Several of the traditional performance tests are not applicable to this instrument due to its operating principles and design. These include zero drift, variations, rise and fall times and noise.

Calibration

Calibrations conducted on February 11, 1976 produced the following points with the curve shown on Figure 6.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
163	14.2
321	28.1
496	43.9
690	59.1
807	72.0
925	82.3

TABLE 17: PERFORMANCE TEST SUMMARY
BECKMAN 6800

Range: 0-1000 ppm CO

Precision: 163 ppm standard - 0.69 ppm*
127 ppm standard - 0.08 ppm
807 ppm standard - 1.35 ppm*
1060 ppm standard - 1.17 ppm

Noise: Not Applicable

Interference: CO_2 - None
H_2O - None

Zero Drift: None

Span Drift:

<u>163 ppm standard</u>

0 hr. - 0.1% of full scale
24 hr. - 0.1% of full scale*

<u>807 ppm standard</u>

0 hr. - 0.7% full scale
24 hr. - 0.8% full scale*

*Average

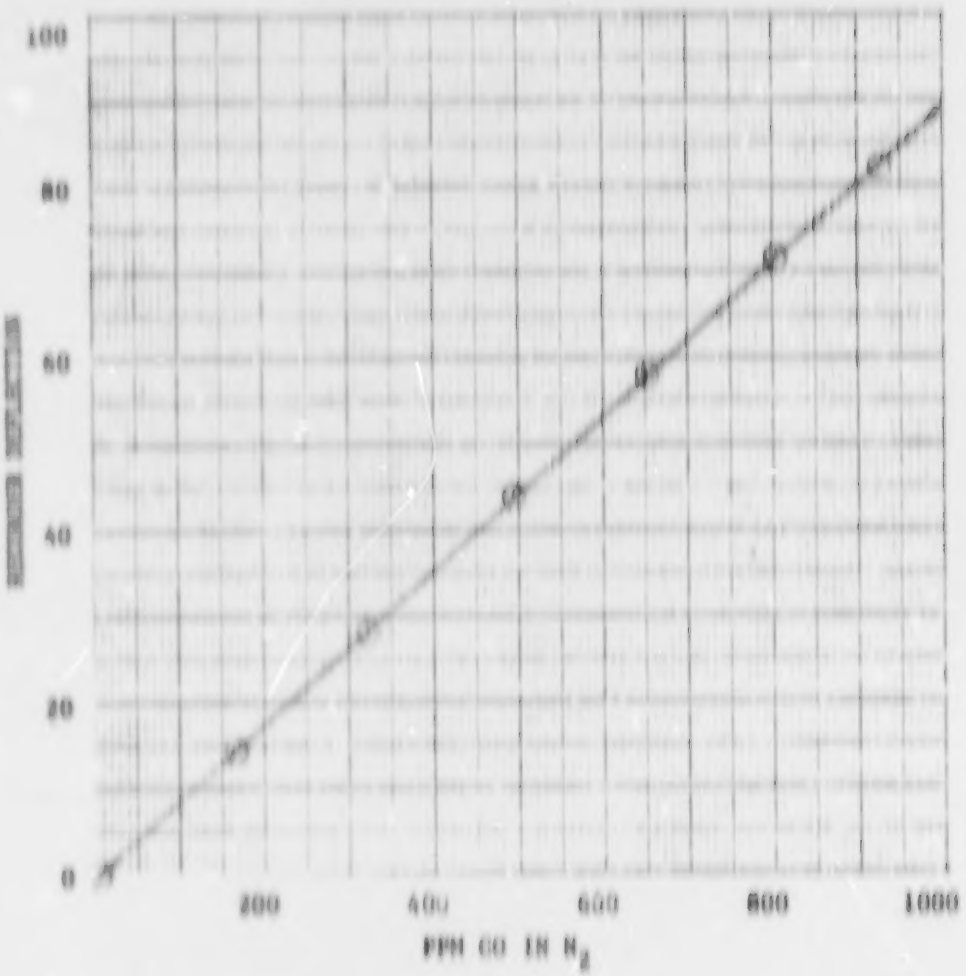

FIGURE 6 BECKMAN 6800 CALIBRATION CURVE

Precision

Tests for precision were performed in November 1975 and February 1976. The results are shown below.

November 1975

Low Concentration (P_L)
Calibration Standard = 127 ppm CO

High Concentration (P_H)
Calibration Standard = 1060 ppm CO

	P_L Instrument Response (ppm)	P_H Instrument Response (ppm)
P_1	127	1060
P_2	127	1059
P_3	127	1060
P_4	129	1059
P_5	129	1058
P_6	128	1057
	P_L = 0.98 ppm	P_H = 1.17 ppm

Low Concentration (P_L)
Calibration Standard = 163 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	161	161
P_2	161	161
P_3	160	161
P_4	160	161
P_5	160	161
P_6	159	-
P_L	1.38 ppm	0 ppm

High Concentration (P_H)
Calibration Standard = 807 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	807	807
P_2	807	-
P_3	806	809
P_4	804	806
P_5	807	-
P_6	807	-
P_H	1.2 ppm	1.9 ppm

Noise

Tests for noise are not applicable to this instrument's non-continuous output.

Response Time

Traditional response times do not apply to a chromatographic type instrument. The instrument completes one analysis cycle every 5 minutes.

Interference

There is no CO_2 interference due to the column separation of component gases.

Temperature Variation

The effects of ambient temperature variation are shown below.

8/12/76

		Instrument Response (Chart Units)	
Time	Temp. (°F)	161 ppm	807 ppm
0930	60	14.1	74.1
1300	70	14.9	74.7
		0.8	0.6
	Equiv. ppm	7.0	5.1

2/13/76

Time	Temp. (°F)	321 ppm
1000	56	31.2
1200	48	31.6
		0.4
	Equiv. ppm	4.1

Flow Variation

The effects of variations in input flow rates are negated by the instrument's internal sample pump and bypass system.

Zero and Span Drift

Zero Drift: Zero drift is corrected by an auto-zero circuit that resets electrical zero during each analysis cycle.

Span Drift: Calibration standard: 163 ppm CO

		Instrument Response (% of full scale)			
Date	Temp. (°F)	S_n	S_{n-1}	Drift (ΔS)	Equiv. ppm
8 hour					
2/27	68	15.4	15.5	-0.1	-1.1
24 hour					
2/11-12	70	14.1	14.2	-0.1	-1.1
2/25-26	68	15.6	15.5	0.1	1.0
2/26-27	68	15.5	15.6	-0.1	-0.1
Calibration Standard: 807 ppm CO					
8 hour					
2/27	68	75.5	76.2	-0.7	-7.5
24 hour					
2/11-12	70	74	72.2	1.8	19.9
2/25-26	68	76.5	76.8	-0.3	-3.2
2/26-27	68	76.2	76.5	-0.3	-3.2

3.2.4 Beckman NDIR Model 865 (Serial No. 01002601)

The Beckman Model 865 was not obtained until late November and it was immediately placed in field test service. The performance tests presented below were, therefore, conducted after the field program. A summary of the lab performance data is shown in Table 18.

Calibration

Calibration performed by Scott on February 11, 1976 produced the following points with the curve shown in Figure 7.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
161	21
321	37.5
496	54.1
650	67
807	78.4
925	86.3

Precision

Tests for precision were performed in February 1976 using both the 161 ppm and 807 ppm calibration standards. The results are shown below.

Low Concentration: 161 ppm Standard

	Instrument Response (ppm CO)	
	Test 1	Test 2
P_1	161	161
P_2	164	164
P_3	161	164
P_4	164	165
P_5	161	160
P_6	161	165
	P_L = 0.52 ppm	P_L = 1.9 ppm

TABLE 18. PERFORMANCE TEST SUMMARY
BECKMAN 865

Range: 0-1000 ppm CO

Precision: Calibration Standard 163 ppm CO = 1.21 ppm*
Calibration Standard 807 ppm CO = 3.25 ppm*

Noise: Nitrogen Zero = 0.6 ppm
807 ppm CO = 0.94 ppm

Response Times: Rise = 5.4 seconds
Fall = 6.5 seconds

Interference: 15% CO_2 = 3.4 ppm
10% H_2O = 1.7 ppm

Zero Drift: 12 hour continuous = 4.4 ppm*
24 hour = 0.4% of full scale*

Span Drift: Calibration Standard = 163 ppm CO
8 hour = 0% of full scale
24 hour = 0.38% of full scale*
Calibration Standard = 807 ppm CO
8 hour = 0.9% of full scale
24 hour = 1.4% of full scale*

*Average

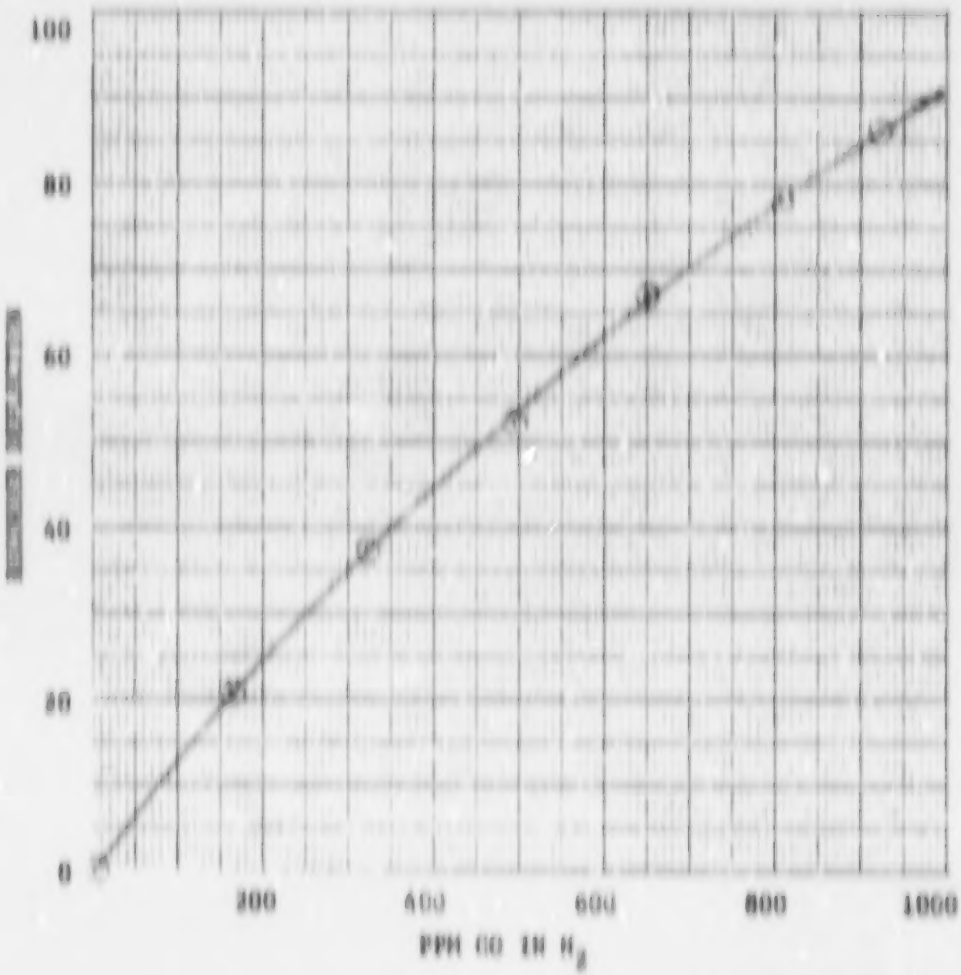

FIGURE 7 BECKMAN 865 CALIBRATION CURVE

High Concentration: 807 ppm Standard

	Instrument Response (ppm CO)	
	Test 1	Test 2
P_1	807	807
P_2	810	814
P_3	807	815
P_4	811	817
P_5	810	809
P_6	813	817
	P_L = 2.3 ppm	P_L = 4.3 ppm

Noise

Tests for instrument noise were conducted on February 10, 1976 using nitrogen zero gas and the 807 ppm standard. The data are shown on Table 19.

Response Time

The response characteristics of the Beckman NDIR were tested using the 807 ppm CO standard. The following results were obtained:

Rise Time = 5.4 seconds

Fall Time = 6.5 seconds

Interference

O_2 interference was tested on the 0-1000 ppm CO range using 15% CO_2 in nitrogen. Response as measured with a digital volt meter was 3.36 ppm. Instrument response to the input of 10% water vapor was 1.7 ppm as measured with a digital voltmeter.

Temperature Variation

The effects of variations in ambient temperature on instrument response are shown below. Responses to the new temperatures were measured shortly after a stable reading was obtained to minimize the effects of instrument drift.

TABLE 19. NOISE TEST DATA

Applicant _____ Date _____

Test No. _____

Analyzer _____ Range _____

READING NUMBER (i)	TIME	95 of URL		85 of URL	
		DB READING	t_i, sec	DB READING	t_i, sec
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
$\sum_{i=1}^{n} t_i$					
$\sum_{i=1}^{n} t_i^2$					
t_0			t_0 =		t_{85} =

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Date/Time	Temperature	Instrument Response (Chart Units)		
		Zero	163 ppm	807 ppm
2/12/76 @ 0900	70°	0	30.2	78.2
@ 1300	80°	0	30.8	80
Response Change (Chart Units)		0	+0.6	+1.8
Equivalent ppm		0	+3.1	+18.4
2/13/76 @ 0900	56°	0	30.5	79.8
@ 1150	68°	0	30.8	79.3
Response Change (Chart Units)		0	+0.3	0
Equivalent ppm		0	+3.1	0

Flow Variation

The effects of sample flow rate variations were measured with the digital voltmeter. Flows were varied from 0 to 5.0 litres per minute. The recommended flow is 0.5-1.0 litres/minute. The results are as follows:

Flow Rate (Liter/Minute)	Instrument Response (ppm)
0	806
0.86	807
1.65	808
3.65	812
5.00	819

Zero and Span Drifts

Zero and span drifts for the Beckman 865 are presented below. Included are 12 and 24-hour zero drifts, mid-range span drift (163 ppm) and high-range span drift (807 ppm).

12-Hour Continuous Zero Drift

	2/10/76	2/11/76	2/12/76
Maximum	9.3 ct. units	10.1 ct. units	10.2 ct. units
Minimum	8.9	9.7	9.7
12 Hour Drift	0.4 ct. units = 4.1 ppm	0.4 ct. units = 4.1 ppm	0.5 ct. units = 5.0 ppm

24-Hour Zero Drift

Date	Temp.	Instrument Response (% of Full Scale) Z_n	Z_{n-1}	Drift (ΔZ)	Equiv. ppm
2/11-2/12	70	9.8	9.6	0.2	2.1
2/12-2/13	60	9.9	9.8	0.1	1.0
2/24-2/25	68	7.0	7.2	-0.2	-2.1
2/25-2/26	68	6.1	7.0	-0.9	-9.3
2/26-2/27	68	5.5	6.1	-0.6	-6.2

Span Drift

Calibration Standard - 103 ppm CO

Date	Temp.	Instrument Response (% of Full Scale) M_n	M_{n-1}	Drift (ΔZ)	Equiv. ppm
8-Hour Drift					
2/27		19.5	19.5	0	0
24-Hour Drift					
2/11-2/12	70	20.2	20.3	-0.1	-1.0
2/12-2/13	60	20.4	20.2	0.2	2.1
2/24-2/25	68	21.0	21.1	-0.1	-1.0
2/25-2/26	68	20.2	21.0	-0.8	-8.3
2/26-2/27		19.5	20.2	-0.7	-7.2

Calibration Standard - 807 ppm CO

8-Hour Drift					
2/27		73.9	74.8	-0.9	1.8
24-Hour Drift					
2/11-2/12	70	79.9	78.3	1.6	16.3
2/12-2/13	60	79.1	99.9	-0.8	-8.2
2/24-2/25	68	68.5	79.5	-1.0	-11.2
2/25-2/26	68	76.7	78.5	-1.8	-18.4
2/26-2/27	68	75.0	76.7	-1.7	-18.2

3.2.3 Horiba MOIR - Model AIA-2 (Serial No. 306622)

Laboratory performance evaluation of the Horiba Model AIA-2 was performed prior to the field program. A summary of the laboratory results is shown in Table 20.

Calibration

Calibration of the Horiba instrument on the 0-1000 ppm CO range produced the following data points. The calibration curve is shown in Figure 6.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
100	8.5
171	13.5
496	52.0
650	67.0
1060	100.0

Precision

The test for precision using the 650 ppm CO standard produced the following data:

	Instrument Response (ppm)
P_1	650
P_2	655
P_3	650
P_4	655
P_5	669
P_6	664

P_H = 7.73 ppm

Noise

Tests for noise were not conducted on the Horiba AIA-2.

Response Time

The rise and fall using 1060 ppm CO standard were 10.9 and 9.5 seconds, respectively.

TABLE 20. PERFORMANCE TEST SUMMARY

HORIBA NDIR MODEL AIA-2

Range: 0-10000 ppm CO

Precision: Calibration standard - 650 ppm CO - 7.73 ppm

Noise: Not Tested

Response Time: Rise - 15.9 seconds
Fall - 9.4 seconds

Interference: 15% CO_2 - 40.9 ppm
H_2O - Not Tested

Zero Drift: 24 hour - 11.7 ppm

Span Drift: 24 hour - 0.5% of full scale*

*Average

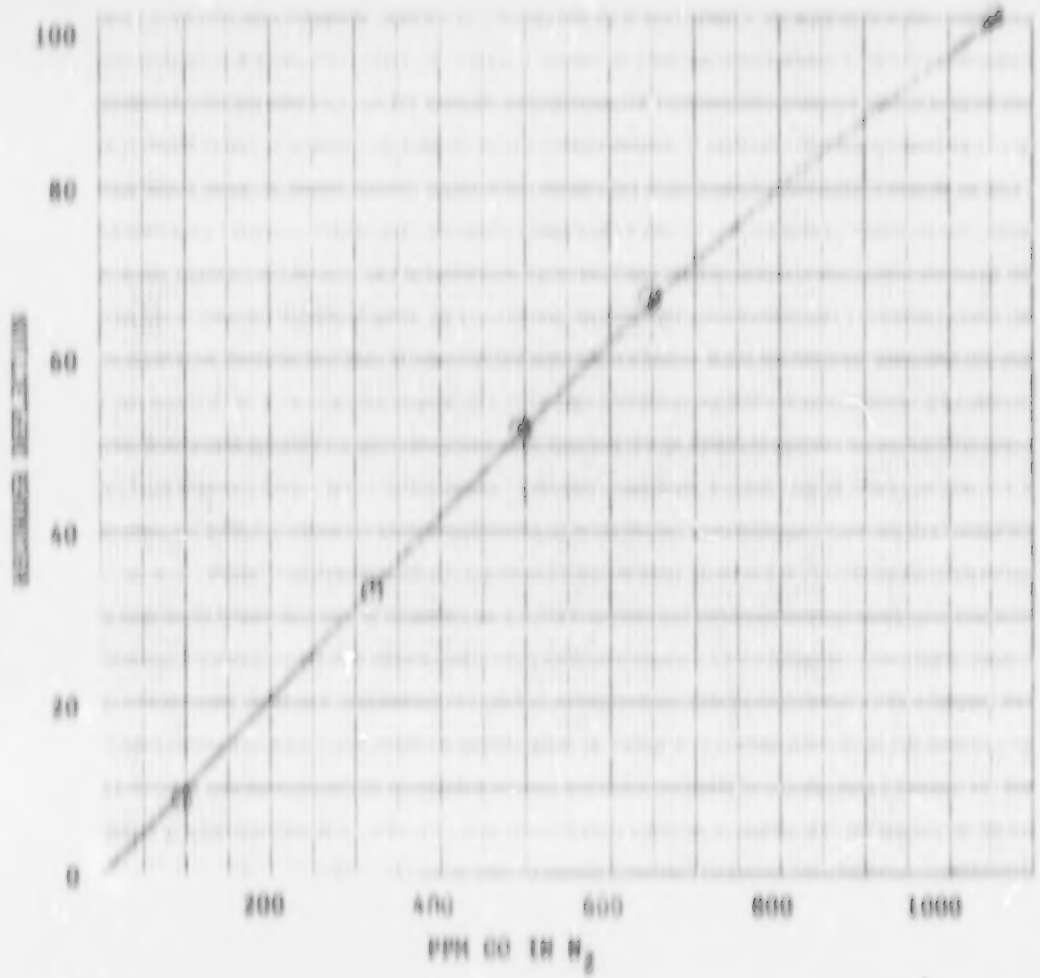

FIGURE 8 HORIBA AIA-2 CALIBRATION CURVE

Interference

The results of the CO_2 interference test are shown below:

Response to 15% CO_2 = 40.9 ppm CO

Tests for H_2O interference were not conducted on this instrument.

Temperature

Tests for temperature variation were not conducted on the Horiba AIA-2.

Flow Variation

Tests for flow variation were not conducted on the Horiba AIA-2.

Zero and Span Drifts

Zero Drift

The zero drift was measured over a period of 25 hours. A 11.7 ppm drift was measured on the 1000 ppm range. Test data is shown below:

Date	Time		Output
10/9/75	1600 hrs.	=	0.522 volts
10/10/75	1500 hrs.	=	0.576 volts
Zero Drift (25 hours)		=	40.054 volts
		=	11.7 ppm

Span Drift

Span drift obtained from records of daily span checks with 650 ppm CO.

Range 0-1000 ppm CO

Date	Response (Chart Units)	Drift (% of Full Scale)
12/11	70	0
12/12	70	0
12/13	69	-1.0
12/14	69	0
12/15	69 (adj. to 66.5)	0
12/16	66	+0.5
12/17	67	+1.0
12/18	66	-1.0

5.2.6 Horiba NDIR Model AIA-21AS (Serial No. 452613011)

The Horiba Model AIA-2 was replaced during the field program by the newer model AIA-21AS. Laboratory testing of the model AIA-21AS was, therefore, conducted after the field program. A summary of these performance tests is shown in Table 21.

Calibration

Calibration performed on February 3, 1976 on the 0-1000 ppm CO range produced the following data with the curve presented on Figure 9.

CO Concentration (ppm)	Instrument Response (Chart Units)
0	0
161	31.2
321	60.6
490	90.6
650	68.8
807	79.0
929	85.5

Precision

Tests for instrument precision using the 161 ppm and 807 ppm standards are shown below.

Calibration Standard: 161 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	161	161
P_2	166	161
P_3	165	160
P_4	166	159
P_5	165	159
P_6	167	158
	P_L = 1.4 ppm	P_L = 1.8 ppm

TABLE 21. PERFORMANCE TEST SUMMARY
HORIBA NDIR MODEL AIA-21AS

Range: 0-1000 ppm CO

Precision: Calibration Standard 163 ppm CO - 1.6 ppm*
Calibration Standard 807 ppm CO - 3.2 ppm*

Noise: Nitrogen zero - 0.47 ppm
Calibration Standard 807 ppm CO - 2.1 ppm

Response Times: Rise - 7.9 seconds
Fall - 10.0 seconds

Interference: 15% CO_2 - 3.6 ppm
10% H_2O - 0.9 ppm

Zero Drift: 12-hour continuous - 4.9 ppm*
8-hour - 0.4% of full scale
24-hour - 0.18% of full scale*

Span Drift: Calibration Standard 163 ppm CO
8 hour - 0% of full scale
24 hour - 0.16% of full scale*
Calibration Standard 807 ppm CO
8 hour - 0.7% of full scale
24 hour - 0.98% of full scale*

*Average

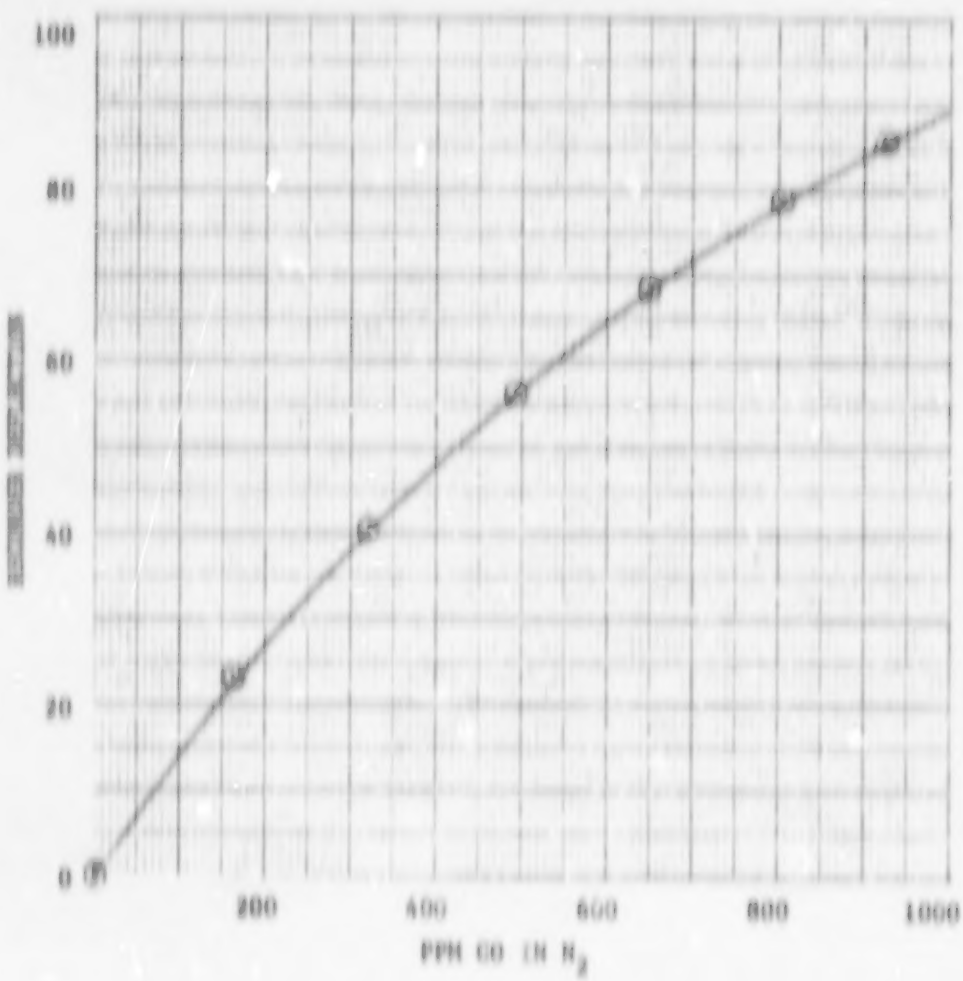

FIGURE 9 HORIBA AIA-21AS CALIBRATION CURVE

Calibration Standard: 807 ppm

	Instrument Response (ppm)	
	Test 1	Test 2
P_1	807	807
P_2	803	807
P_3	807	806
P_4	807	807
P_5	812	809
P_6	815	813
	P_H = 4.2 ppm	P_H = 2.2 ppm

Noise

The test for instrument noise was conducted using nitrogen zero gas and the 807 ppm standard. The results are shown in Table 12.

Response Time

Response time for the Horiba AIA-21AS using the 807 ppm calibration standard are shown below.

2/11/76

Rise Time = 8.1 Seconds

Fall Time = 10.0 Seconds

2/12/76

Rise Time = 7.8 Seconds

Fall Time = 10.0 Seconds

Interference

H_2O and CO_2 interferences were measured using a digital voltmeter. The response to the addition of 10% water vapor was equivalent to -0.5 ppm CO, and the response to the addition of 15% CO_2 in N_2 was equivalent to +3.5 CO ppm.

TABLE 22. NOISE TEST DATA

Applicant _____ Date _____

Test No _____

Analyzer _____ Range _____

READING NUMBER (i)	TIME	95% of URL		99% of URL	
		DM READING	t_i, ppm	DM READING	t_i, ppm
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
$\sum_{i=1}^{n} t_i$					
$\sum_{i=1}^{n} t_i^2$					
$\bar{t}$			$\bar{t}_{95}$ =		$\bar{t}_{99}$ =

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Temperature Variation

Variations in instrument response due to temperature changes are shown below:

Time	Temp.	Instrument Response (Chart Units) Zero	163 ppm	807 ppm
2/12/76				
0900	70°	8.7	24.0	80.8
1700	60°	9.8	25.2	85.1
		1.1 =	0.2 =	2.3 =
		10.8 ppm	2.0 ppm	22.6 ppm
2/13/76				
0845	50°	10.1	24.6	83.1
1150	48°	10.1	25.0	84.4
		0	0.4 =	1.1 =
			3.9 ppm	10.8 ppm

Flow Variation

The effects of flow variation as measured by the digital voltmeter were as follows: The recommended range for the instrument is 1-10 liter/minute.

Flow (Liter/Minute)	MV Response	Equiv. ppm
0	847	807
0.84	846	806
1.45	847	807
2.6	847	807
5.0	850	810

Zero and Span Drifts

Tests for instrument drift are presented below. Included are hourly zero drift and mid-range and high-range span drifts.

Zero Drift

12-Hour Continuous Zero Drift

	12/10/75	12/11/75	12/12/75
Maximum	9.5 ct. units	9.0 ct. units	10.1 ct. units
Minimum	9.0	8.6	9.6
12 Hour Drift	0.5 ct. units	0.4 ct. units	0.5 ct. units
	= 5.0 ppm	= 4.6 ppm	= 5.2 ppm

6 and 24-Hour Zero Drift

Date	Temp.	Instrument Response (% of Full Scale) Z_n	Z_{n-1}	Drift (AZ)	Equiv. ppm
6-Hour					
2/27	68	5.4	5.8	-0.4	-4.2
24-Hour					
2/11-2/12	70	8.7	8.7	0	0
2/12-2/13	60	10.1	9.9	0.2	2.0
2/24-2/25	68	6.0	6.6	-0.6	-6.3
2/25-2/26	68	6.0	6.0	0	0
2/26-2/27	68	5.9	6.0	-0.1	-1.0

Span Drift

Calibration Standard: 103 ppm CO

Date	Time	Instrument Response (% of Full Scale) S_n	S_{n-1}	Drift (AS)	Equiv. ppm
6-Hour					
2/27		22.5	22.5	0	0
24-Hour					
2/11-2/12	70	23.7	23.2	0.4	4.0
2/12-2/13	60	24.6	24.1	0.5	5.0
2/24-2/25	68	22.9	23.4	-0.5	-5.0
2/25-2/26	68	22.8	22.9	-0.1	-1.0
2/26-2/27		22.5	22.8	-0.3	-3.0

Calibration Standard: 807 ppm CO

Date	Temp.	Instrument Response (% of Full Scale) S_n	S_{n-1}	Drift (ΔS)	Equiv. ppm
8-Hour					
2/27		75.3	76.0	-0.7	-7.4
24-Hour					
2/11-2/12	70	80.7	78.8	1.9	19.2
2/12-2/13	60	83.2	82.2	1.0	10.1
2/24-2/25	68	71.7	78.0	-6.3	-63.1
2/25-2/26		76.0	76.7	-0.7	-7.1
2/26-2/27		76.0	76.0	0	0

SECTION 6

FIELD PERFORMANCE EVALUATION

6.1 SITE SELECTION, DESCRIPTION AND PREPARATION

Site selection was based on the following criteria:

- Availability of a continuous carbon monoxide source in the range of 500 - 1000 ppm.
- Accessibility of site for equipment and testing.
- Availability of instrument housing.
- Proximity of site to Scott's Plumsteadville laboratory.

The source chosen for the field program was the outlet duct from an electrostatic precipitator exhausting flue gas from two carbon monoxide boilers. These are waste heat boilers that receive flue gas from the catalyst regenerator section of the catalytic cracking unit. These input flue gases contain high concentrations of carbon monoxide and are at very high temperatures. The CO boilers recover heat from the hot regenerator gases, convert CO contained in these gases to CO_2 and take advantage of the heat created by this conversion, as well as the heat recovered to generate steam.

The boilers are controlled by a Buell electrostatic precipitator and a Lodge-Cottrell precipitator ducting to a common stack. The configurations of the precipitators and stack is shown in Figure 10.

Preliminary information indicated the following stack conditions:

- Carbon Monoxide - 500-1000 ppm
- Carbon Dioxide - 10-13%
- Moisture - Approximately 10%
- Temperature - 500°F

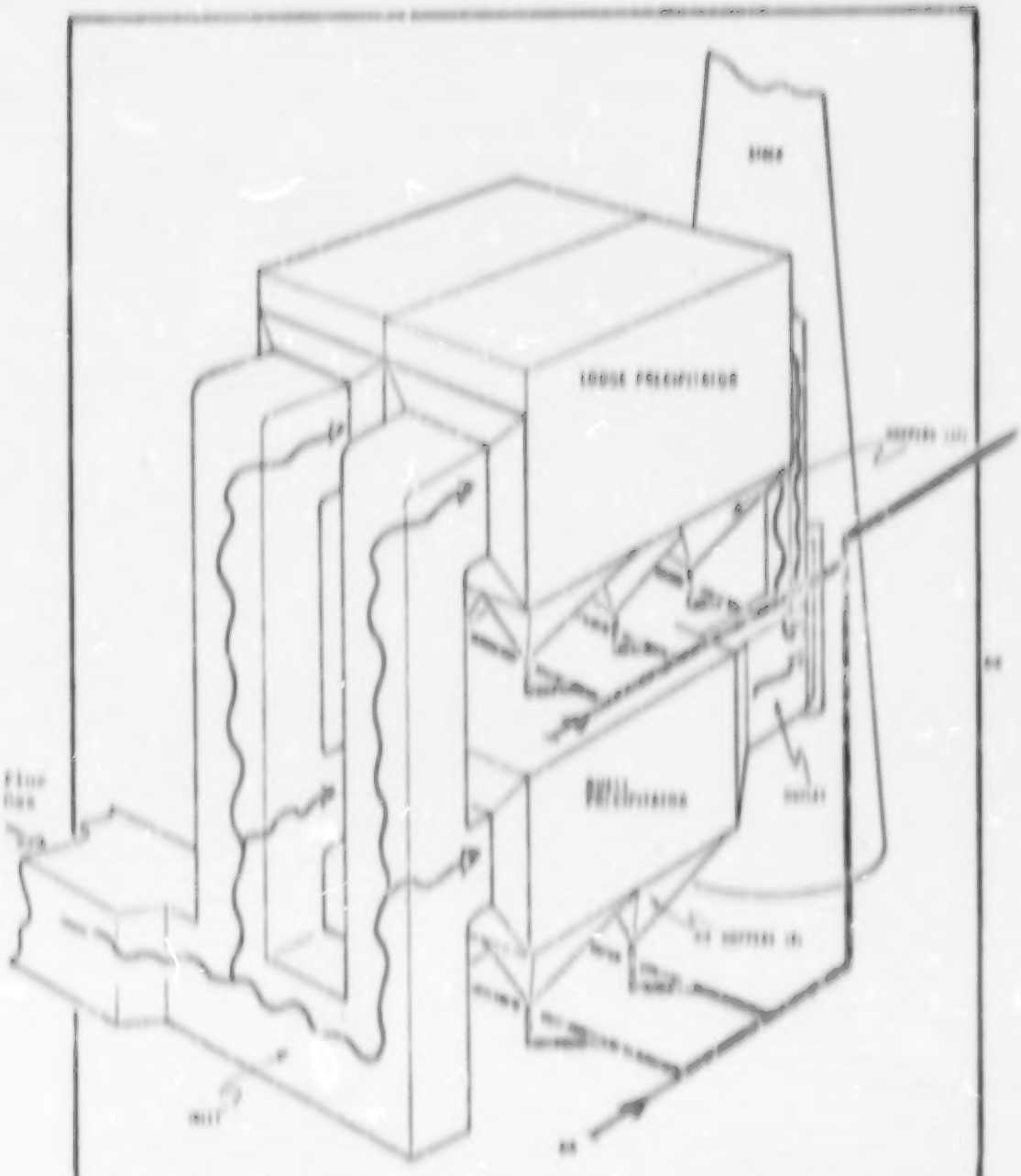

FIGURE 10 CONFIGURATIONS OF PRECIPITATORS AND STACK

- Pressure - Approximately Atmospheric
- Flow - Approximately 160,000 ACFM
- Particulate (EPA Method 5) - 1 gr/SCF
- SO_x - 500 ppm (maximum)

Arrangements were made to install the sampling system and instrumentation during a routine outage for maintenance. At this time, the ERT monitor was mounted on the duct and the extractive sampling system was installed. A compact trailer was provided for instrument housing with provisions for power and lighting.

The catalytic cracker became operational during the first week in November; however, normal operating conditions were not achieved until the following week. During this period, the necessary probe placement and instrument check-out were performed.

During the field program, several process upsets occurred. This was usually the result of #2 boiler being shut down although at one time both #1 and #2 boilers were down.

When #2 boiler was in upset condition, the flow of input gas from the hot regenerator would be bypassed to a secondary stack and exhausted combustion air to #2 boiler would remain on. Therefore, the boiler effluent discharging through the precipitators and past the sampling ports would be diluted and the CO concentrations decreased along with the stack temperature. These periods are indicated in the field data summary.

6.2 FIELD SAMPLING SYSTEM

The sampling system designed by Scott for the field evaluation phase of the project provided for the continuous operation of the five CO monitors at the refinery site. In addition, flow rates, duct and instrument trailer temperatures and moisture levels were monitored periodically along with the continuous recording of CO_2 by ORSA.

Four of the monitors being evaluated required sample extraction and conditioning. These instruments were located in a compact trailer 35

meters below the sample ports. The fifth instrument was an in-situ cross-stack infrared analyzer with only its recorder located in the trailer.

A schematic diagram of the sample ports and delivery system is shown in Figure 11.

6.2.1 Sample Port Location

The optimum location for sampling was on the outlet duct from one side of the Lodge-Cottrell precipitator. This duct had existing platforms, was easily accessible, and posed minimum problems regarding the installation of the ERT cross-stack monitor. Also, five ports were available on this duct for sample probe placement, velocity traverses, moisture determinations, and ancillary testing.

6.2.2 Probe

The probe was fabricated from 1/8" stainless steel tubing. The end of the tubing was capped and five inlet holes were drilled so that sample would be drawn from the centers of five equal areas across the duct. The probe was inserted through a 4" port cap using a swage-lock fitting and oriented with the inlet holes facing downstream. A three-way valve and blower were installed at the outlet of the probe for daily purging of particulate matter.

6.2.3 Stack-Mounted Water Trap

Immediately following the probe assembly was a water trap to prevent condensed water from freezing in the sample line. The trap originally consisted of four 500 ml glass impingers in a water bath. The last impinger contained glass wool for filtering particulate. Water collected in these impingers was emptied during routine field visits.

This impinger water trap was replaced on December 23 with refrigeration coils immersed in a water bath. This version was automated so that collected water would be purged hourly while the instruments below were in the hourly zero mode. These functions along with the purging of a second condenser system in the trailer and the purging of the probe were controlled by solenoids activated by a master timer in the trailer.

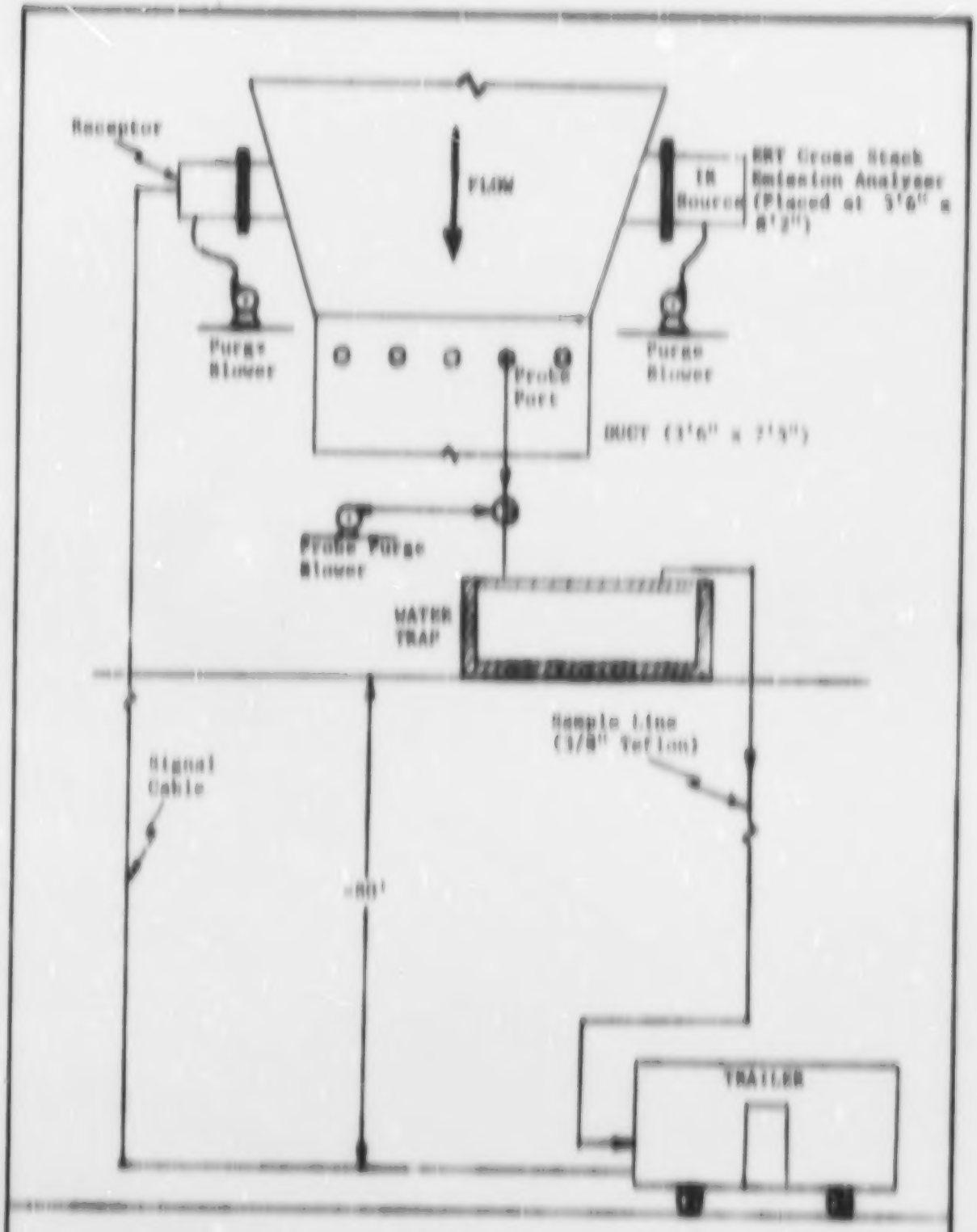

FIGURE 11 SAMPLING LOCATION AND SAMPLE FLOW TO INSTRUMENT TRAILER

A refrigeration type of condenser was not permitted at the probe location due to safety requirements and, therefore, the moisture level in the sample gas was derived by the water bath temperature. Since this was partially warmed by stack radiation, enough moisture was present in the sample to freeze in the sample line during very cold periods.

6.2.4 Sample Transport System

Sample was transported from the stack to the instrument trailer through a 3/8" teflon line. A diaphram pump with a free capacity of 6.0 CFM was used, providing a sample transport time of approximately 5 seconds. Sample in excess of that required for the instruments was bypassed to minimize transport time.

6.2.5 Sample Conditioning Components

Sample conditioning involved particulate and moisture removal. Figure 12 shows the arrangement of the sample conditioning components in the trailer.

Filtration was accomplished by a heated 3" diameter fiberglass filter located before the sample pump and condenser unit and an unheated 3" fiberglass filter after the condenser.

Water vapor was reduced to approximately 0.5% by a refrigerated condenser. This condenser was automatically purged hourly while the instruments were in the zero mode.

6.2.6 Auto-Zero Solenoid and Master Timer

Following the conditioning components sample was routed to the auto-zero solenoid. This solenoid interrupted sample flow and routed nitrogen zero gas through the instruments in the trailer for three minutes every hour. This solenoid was activated by a master timer that also controlled the purging of both water condensers and the probe.

6.2.7 Sample Manifold and Control Console

The sample manifold and control console is shown in Figure 13. The manifold, which received sample from the auto-zero solenoid had five

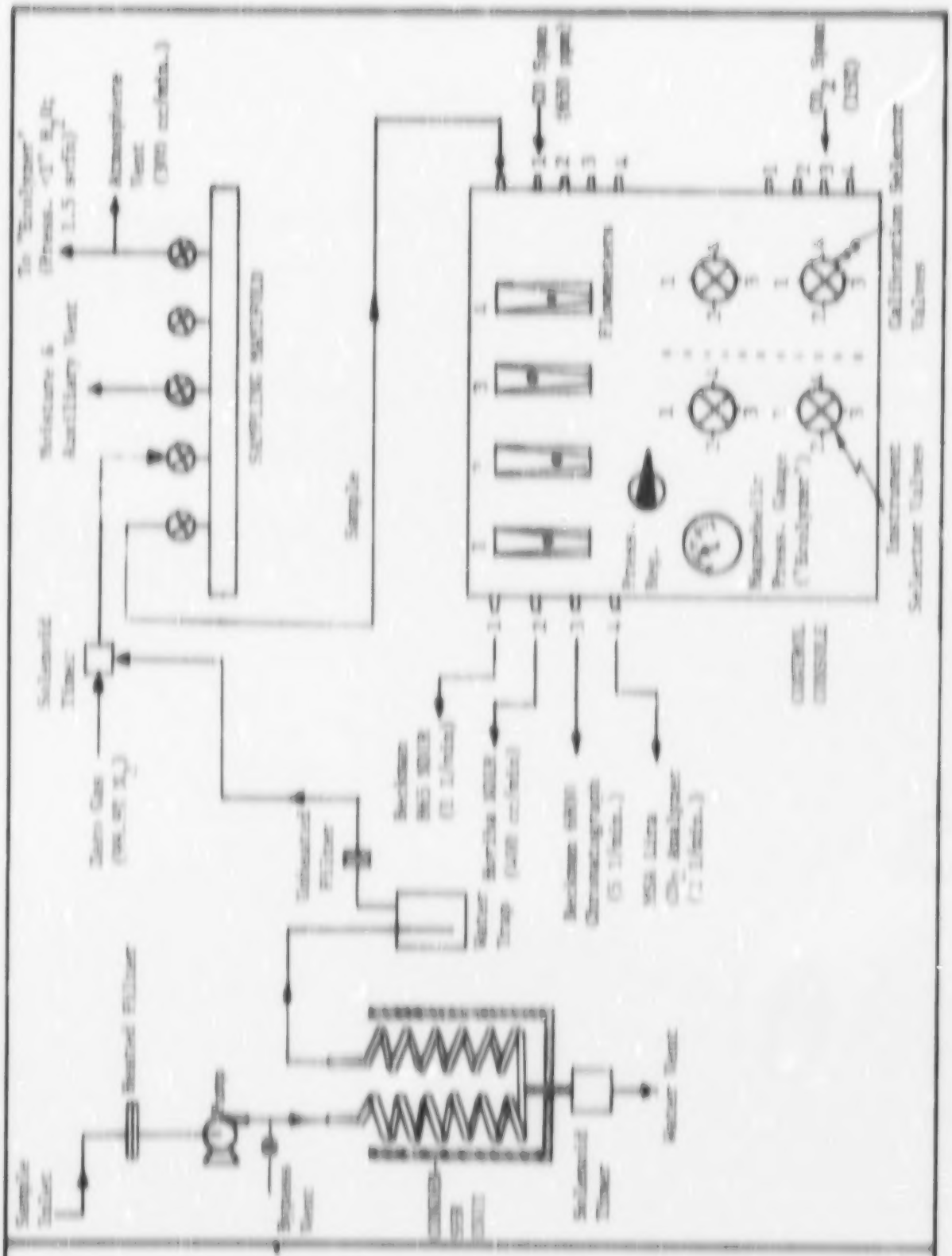

FIGURE 12 Sampling Manifold and Control Console

ports for sample distribution to the instruments and for any ancillary testing. One port on the manifold was used to supply sample to the control console for distribution to the Horiba NDIR, Beckman NDIR, Beckman chromatograph and MSA CO_2 monitor. A second manifold port was used to provide sample to the Ecolyzer which was controlled independently in order to maintain a sample pressure of less than 1" H_2O as per instructions. Another port was used to measure sample moisture content.

The control console was used to distribute both sample and calibration gas flow to each instrument. The console contained flow meters and selector valves for convenient selection and regulation of gas flow to each instrument.

6.2.8 Calibration Gases

All instruments, except the FID's, were spanned with Scott "close tolerance" (±2% analysis) blends of carbon monoxide in nitrogen. The following six concentrations covering the 0-1000 ppm range were available in the instrument trailer: 100 ppm, 321 ppm, 496 ppm, 659 ppm, 807 ppm and 935 ppm. The MSA CO_2 monitor was spanned with a Scott blend of 15% CO_2 in nitrogen. Zero gas used for both routine calibrations and automatic hourly zeroes was Scott 99.995% pure nitrogen. All of these gases were connected to the gas inputs on the control console for convenient selection and control.

The Ecolyzer, however, due to its sample pressure sensitivity, was spanned by filling Tedlar bags with the appropriate gas at the control console and allowing the instrument to draw gas, at its own rate, into the detector cell.

6.2.9 System Performance

The sample delivery/conditioning system performed adequately throughout the program with the exception of several sample line freeze-ups. This freezing condition was often due to the simultaneous occurrence of near zero ambient temperatures and a process upset in #2 boiler.

Other minor problems like broken filters and dirty solenoids

caused brief interruptions in sample flow.

Table 11 outlines all sample flow interruptions to the instruments. During periods where a leak resulted in a diluted sample flow to the instruments comparative evaluation of all but the ERT in situ monitor is still valid.

6.2.10 Data Acquisition

All instrument responses were recorded on individual, continuous strip chart recorders. This includes the stack-mounted ERT instrument recorder in the trailer.

In addition, the Horiba NDIR, Beckman NDIR, Analyzer and ERT responses were recorded on magnetic tape using Westinghouse environmental data loggers. These loggers convert instrument outputs to pulses which are recorded on tape. The pulse frequency recorded is proportional to the input voltage. Additionally, each recorder has a time channel which receives a pulse every 15 minutes for subsequent computer correlation.

Data presented in the Field Data Summary (Section 6.7) for the Horiba NDIR, Beckman NDIR, Analyzer and ERT were computed from data logged on the tapes. Data for the Beckman 6800 and MSA CO_2 monitor were obtained from strip charts.

6.3 FIELD VISITS

Throughout the field program, daily maintenance and calibration visits were required. During each visit, a schedule of procedures, along with any required maintenance, would be followed.

Figure 11 shows the log sheet used for recording calibration and maintenance data during the program.

6.3.1 Daily Calibration

All instruments except the ERT were calibrated daily using the 630 ppm calibration standard and nitrogen zero gas. The ERT was calibrated with its internal calibration unit. The zero and span responses were then recorded on the log sheet along with any adjustments that were required.

In addition to the CO instrument, the MSA CO_2 monitor was calibrated daily using 15% CO_2 in nitrogen.

TABLE 31. SAMPLE FLOW INTERRUPTIONS

Date/Time	Reason	Notes
12/18 1300-4130	Clogged Probe	No Sample
12/22 0900-1600	Clogged Line	No Sample
12/24 0615-1130	Clogged Line	No Sample
12/29 1100-1600	Solenoid Stuck	No Sample
1/2 0600-1415	Frozen Sample Line	No Sample
1/5 @ 1200- 1/6 1330	Frozen Sample Line	Diluted Sample (Partial Flow)
1/9 0300-1400	Solenoid Frozen Open	Diluted Sample (Flow but no CO)
1/10 @ 1400- 1/11 1300	Frozen Sample Line	No Sample
1/11 @ 1430- 1/13 1200	Filter Leak	Diluted Sample
1/14 @ 2200- 1/15 1130	Broken Filter	Diluted Sample
1/16 0500-1200	Broken Filter	Diluted Sample
1/17 @ 1100- 1/20 1200	Leak in Reefer System	Diluted Sample
1/18 @ 1200- 1/20 1400	Frozen Sample Line	Sample Intermittant
1/20 @ 1200- 1/21 1300	Leak in Reefer System	Diluted Sample

DAILY LOG PROJECT 1519

DATE 1/15/82 TIME IN 1030 RANGE(S) 2.10

TRAILER COND. - Ambient Temp: 70 Line Volt: 116

Flowrates O.K. - (Notes)

Change 3 Filters-(Notes)

CYLINDERS H_2 1355 Air 1100 N_2 1500 BSCGO 1500

Notes:

MOISTURE (Every Day): At Manifold

Start Time: 1830 Start Meter: 2997 (.18%) Meter Temp. 58

Stop Time: 1300 Stop Meter: 0762 Meter Temp. 62

Silica gel: Initial wt. 382.0 Final wt. 387.4

INSTRUMENTS: All readings in recorder chart units. Always get zero and span readings before and after any adjustments. Check with lab before adjusting spans.

SO2 (Switch to Cal.): Time: 1230 Recorder: [illegible]

Cal. Reading 20 Notes: [illegible]

BECKMAN 6800: Time: 1315 Recorder: OK

Baseline: 6 Cal. (Cal. std. switch, set flowrate in rear to 0.8) 77

Notes: [illegible]

BECKMAN 865: Time: 1300 Recorder: OK

Zero 4 Gain 8.125, New Zero Gain

Span 77 Gain 198, New Span Gain

Notes:

NO/NOx: Time: 1630 Recorder: OK

Zero 0.8 Gain 2.63, New Zero Gain

Span 76 Gain 196.1, New Span Gain

Notes:

HRA (CO_2): Time: 1100 Recorder [illegible]

Zero 1.63 Gain 5.63, New Zero [illegible] Gain 5.1

(LOW CO_2) Span Off scale Gain [illegible], New Span [illegible] Gain [illegible]

Notes:

DA/OLYSER: Time: 1300 Recorder OK

Zero (switch) 2.0, New Zero

Span (Tedlar bag) 6.5, New Span

Check H_2O Bottle Inside:

Condition of Pre-filter:

Bypass Flow (Outside Trailer) cc/min.

FIGURE 13: SAMPLE OF DAILY LOG SHEET

STACK CHECK-OUT

* Moisture and flows must be done on Tuesday and Thursday unless planned otherwise: (Obtain ice for moisture check from lab.)

FLUE CONTROL ROOM: Time 1130 Baro. Press. (Bar. HG) 29.07

Flow in Brick Stack ✓

Boiler Status OK

STACK ROOM:

Condenser: (Notes) OK, filter cruddy

Check filter (change if necessary): clean filter & OK

MOISTURE: Set up probe, 3 impingers, silica gel tube, pump and flowmeter on middle port. (Sample ~ 10 ft.³)

Start Time 1130 Start Meter 41 30.015 Temp. In 41 Out 46

Stop Time 1230 Stop Meter 51 26.52 Temp. In 51 Out 62

Initial wt: 533.8 Final wt: 556.4

Impinger vol. - Initial 200 ml Final 115

9.1% H2O

Pyrite: Sample Middle Port 1 2 3 CO2

Traverse: Use pitot bridge and monometer. Static -.2

Point	Port A (on left)	Port B	Port C	Port D
1	1.3 in. ____ "H	.8 in. ____ "H	.92 in. ____ "H	1.3 in. ____ "H
2	1.5 in. ____ "H	.6 in. ____ "H	1.0 in. ____ "H	1.5 in. ____ "H
3	1.5 in. 1.00 "H	.6 in. 1.12 "H	1.0 in. 1.00 "H	1.4 in. 1.44 "H
4	1.3 in. ____ "H	.6 in. ____ "H	1.1 in. ____ "H	1.2 in. ____ "H
5	1.1 in. ____ "H	.7 in. ____ "H	1.0 in. ____ "H	1.1 in. ____ "H

REMARKS: ____

Time Leaving Site: 1315

Return form, silica gel tubes, charts (every 3-4 days) to Scott.

Supplies Needed: none of either type

WK 6, WK 7 orsat.

Problems Unsolved Upon Leaving:

None

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FIGURE 11. (Continued) SAMPLE OF DAILY LOG SHEET (Page 2)

6.3.2 Weekly Calibrations

On Monday of each week, a comprehensive calibration was conducted using all six span gases available in the trailer. These gases included 100, 321, 496, 650, 807 and 929 ppm CO.

6.3.3 System Maintenance

Maintenance activities required on a daily basis included emptying the condensed water from the impinger water trap at the stack, purging the probe and changing the filters in the instrument trailer. Daily maintenance on the stack was eliminated by the installation of the automated condenser system on December 23. The remaining components of the sampling system would be checked and maintained as necessary.

Other routine maintenance items included recording gas cylinder pressures and making any necessary replacements and maintaining the continuous recorders on the instruments.

6.3.4 Ancillary Data Acquisition

During each field visit, the trailer temperature, line voltage, barometric pressure and sample moisture level would be recorded. Moisture was determined using a pre-weighed silica gel tube and dry test meter. Sample was obtained from a vacant port on the sample manifold.

Twice per week the flow rate, temperatures, pressure, moisture and CO_2 level in the duct would be measured. This involved a complete traverse using a type "S" pitot tube and thermocouple along with the CO_2 check using a fyrite. Moisture determinations were made using a pre-weighed silica gel tube with a dry gas meter and pump.

6.4 INSTRUMENT PERFORMANCE AND MAINTENANCE

The following section presents each instrument's overall performance and maintenance records for the field evaluation program. Included are service calls, routine maintenance, malfunctions and resultant down times for each instrument. The daily zero and span responses along with zero and span drifts are also included as an indication of overall performance.

6.4.1 Environmental Research & Technology, Inc. - Stack Gas Monitor (Model 4000)

A review of both the calibration and maintenance log and the field data show that the ERT had chronic problems resulting in a significant amount of lost and questionable data throughout the field program.

Instrument responses were often intermittant, reading correctly at times and then switching suddenly to completely irrational responses. The ERT representative was called three times spending a total of five days at the site repairing the various malfunctions.

Beginning with the November instrument check-out, the ERT service representative was called to replace a defective recorder and replace a power supply apparently caused by the shorting out of a blower used to purge the optics on the IR source unit. This blower remained inoperative for the entire program.

ERT was called again on December 2 and 3 to repair problems caused by overheating when the blower for the IR detector failed. These repairs were apparently unsuccessful because the responses were still intermittant afterward although the blower itself was repaired.

The ERT serviceman returned on December 18 to work on the intermittant response problems but could not effect repairs.

Also, in approximately 50% of the calibration attempts, the instrument would either not respond at all or respond erratically.

Table 9A is the calibration and maintenance log for the ERT instrument.

6.4.2 Energetics Science Inc., Analyzer (Model 3100)

The initial check-out of the Analyzer at the Gun Oil Company site revealed serious SO_2/NO_x interference despite the internal filter incorporated in the instrument. This interference was remedied with a heavy-duty pre-filter supplied by Energetics Science Inc. and installed on December 1, 1975. This filter, which was designed to last over a month, had to be replaced every 2 weeks during the program.

TABLE 24. ERT CALIBRATION AND MAINTENANCE

Date	Time	Calibration Response (% of Full Scale)	Maintenance Notes
12/1	1337	40-97	
12/2	1130	3	ERT Rep. to repair damage caused by shorted blower
12/3	1300	30-90	
12/4	1230		No Cal. Response
12/5	1100		No Cal. Response
12/6	1100	5	Sample Responses Intermittant
12/7	1300		No Cal. Response
12/8	1130	65-70	
12/9	1230	65-72	ERT put on mag. tape
12/10	1200	65-70	
12/11	1530	65-70	
12/12	1400		No Cal. Response
12/13	1705	~6	Erratic Response Intermittant
12/14	1200		No Cal. Response
12/15	1108		No Cal. Response
12/16	1360	61-70	
12/17	1800		No Cal. Response
12/18	1700		No Cal. Response - ERT to repair intermittant response problems
12/19	1414	70	
12/20	1520		No Cal. Response
12/21	1200	60-70	Erratic
12/22	1200		No Cal. Response - Sample Responses Intermittant
12/23	1315	50-60	
12/24	1058	39	
12/25		NO ROUTINE VISIT	
12/26	1157		Erratic Calibration Response
12/27		NO ROUTINE VISIT	
12/28	1330		No Cal. Response

TABLE 2(CONT'D) ERT CALIBRATION AND MAINTENANCE

Date	Time	Calibration Response (% of Full Scale)	Maintenance Notes
12/29	1200	20-50	Erratic Cal. Response
12/30	1140		No Cal. Response
12/31	1100		No Cal. Response
1/1		NO ROUTINE VISIT	
1/2	1030	65	
1/3		NO ROUTINE VISIT	
1/4	1515	58	
1/5	1330	34-45	
1/6	1200	50-60	
1/7	1715	35	
1/8	1230	6	
1/9	1305	17	
1/10			
1/11	1113	65	
1/12	1235	60	
1/13	1130	60-70	
1/14	1115	70	
1/15	1230	70	
1/16	1121		No Cal. Response
1/17	1090	65	
1/18		NO ROUTINE VISIT	
1/19	1345	70	
1/20	1345	67	Stuck at 40 for last 20 Minutes
1/21	1142	67	
1/22	1200	70-80	
1/23			No Calibration

the Ecolyser had no malfunctions resulting in lost data throughout the field program. It's response to both sample and calibration gas was initially very good. Starting with the second week in January, however, performance began to deteriorate until, by the end of the program, sluggish responses made calibration and performance checks difficult.

Figure 16 is a comparison of routine calibrations showing the difference in response towards the end of the program. The figure shows that the January trace did not flatten out or replicate in the same manner as in early December.

This problem appeared to result from deterioration and/or contamination of the electrochemical detector cell in the instrument. This may have resulted from exposure to the stack gas prior to the installation of the heavy-duty SO_2/NO_x filter. The Ecolyser was purchased new for this program and its detector is specified to last 1 year in use.

Table 25 is the calibration and maintenance log for the Ecolyser. Although there was no lost data due to malfunction there was a few problems with drifts as can be seen from the data.

Although zero drift in most cases was not a problem, the span drift was consistantly very high resulting, during periods of inordinately high drift, in erroneous and unreliable data. The deterioration of the instrument response towards the end of the program, especially to calibration gas input, aggravated this span drift problem because the responses to calibration gas inputs would not replicate or stabilize.

6.4.3 Beckman Air Quality Chromatograph (Model 6800)

The Beckman chromatograph performed very well for most of the field program exhibiting excellent stability and reliability. There was one malfunction, however, that began intermittantly on December 19, 1975 resulting in several flame-outs and resultant lost data. This problem was difficult to diagnose initially due to its intermittant nature and because variations in H_2 fuel and air carrier pressure settings would temporarily remedy the problem. A faulty multi-functional injector valve was finally isolated and repaired by Beckman on January 21.

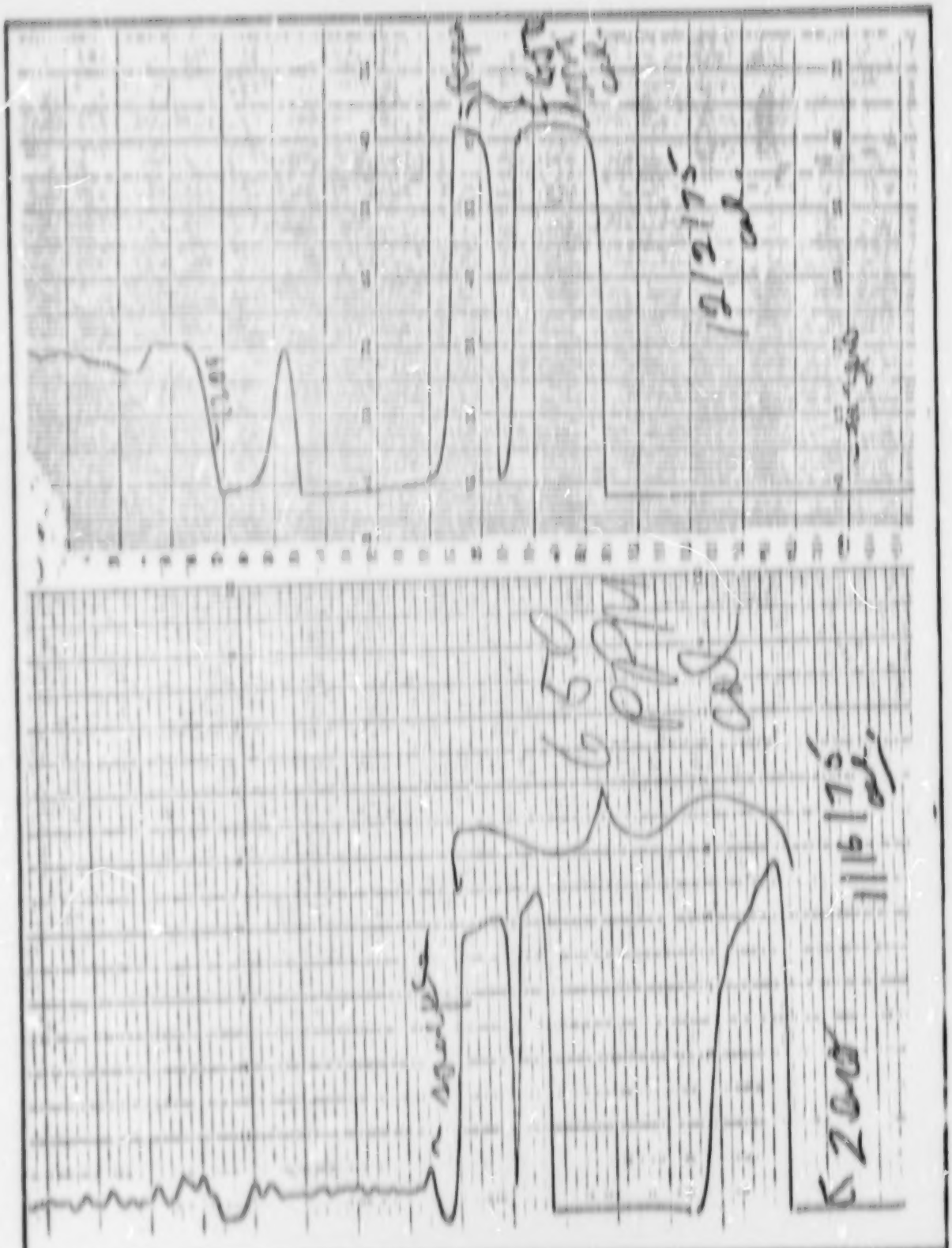

FIGURE 14 COMPARISON OF ROUTINE CALIBRATIONS OF KOOLYSER

TABLE 25. ECOLYZER
CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
12/1	1300	8		64.5		Heavy Duty SO_2/ NO_x filter installed
12/2	1130	8	0	54.0	-10.5	
12/3	1300	7	-1	61.0	+7.0	
12/4	1230	8	+1	55.0	-6.0	
12/5	1100	8	0	54.0	-1.0	
12/6	1100	10	+2	53.0	-1.0	
12/7	1300	10	0	40	-13.0	
12/8	1130	9	-1	59	+19.0	
12/9	1230	14	+5	45	-14.0	
12/10	1200	19/10*	+5	81/65	+36.0	Span Off Scale Refill Humidifier Bottle
12/11	1530	21/10*	+11	79/65*	+14.0	
12/12	1400	9	-1	64	-1.0	
12/13	1705	15	+6	58	-6.0	
12/14	1200	7	-8			
12/15	1108	6/9*	-1	36/65*	-22.0	Replaced Heavy Duty Filter Media (Zero Unstable)
12/16	1300	9	0	72	+7.0	
12/17	1806	10	+1	65	-7.0	
12/18	1200	10	0	62	-3.0	
12/19	1345	10	0	67	+5.0	
12/20	1400	12	+2	68	+1.0	
12/21	1215	5	-7	38	-3.0	
12/22	1145	6/6.8*	+1	45.5/65.5*	+7.5	
12/23	1230	8	+1.2	71.8	+6.8	
12/24	1045	9	+1	70	-1.8	
12/25			NO ROUTINE VISIT			
12/26	1230	16	+7	69	-1.0	
12/27			NO ROUTINE VISIT			
12/28	1315	8	-8	63	-6.0	
12/29	1215	6.0	-1.2	60.2	-2.8	Replaced Heavy Duty Filter Media
12/30	1115	7.5	+0.7	55	-5.2	
12/31	1110	7.8	+0.3	57.5	+2.5	

TABLE 25(CONT'D) ECOLYZER

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
1/1			NO ROUTINE VISIT			
1/2	1110	5	-2.8	59	+1.8	
1/3			NO ROUTINE VISIT			
1/4	1430	9.5	+6.5	61.5	-17.5	
1/5	1305	15	+15.5	39	-2.5	
1/6	1200	7.5	-7.5	44.5	+5.5	Replaced Heavy Duty Filter Media
1/7	1200	5	-2.5	45	+0.5	
1/8	1345	5.8	+0.8	50.2	+5.2	
1/9	1248	6	+0.2	47	-3.2	
1/10			NO ROUTINE VISIT			
1/11	1125	6	0	49	+2.0	
1/12	1230	6	0	48	-1.0	
1/13	1110	7	+1.0	47.5	-0.5	
1/14	1120	9	+2.0	53	+5.5	
1/15	1040	7.5	-1.5	48	-5.0	
1/16	1100	7	-0.5	48	0	
1/17	1025	6	-1.0	51.5	+3.5	
1/18			NO ROUTINE VISIT			
1/19	1300	8	+2.0	46	-5.5	
1/20	1300	7.8	-0.2	40.2	-5.8	
1/21	1125	7.5	-0.3	46	+5.8	
1/22	1200	8	+0.5	45	-1.0	
1/23	1610	8	0	43.2	-1.8	

* Adjustment Made

Note: All span and zero drifts based on 0-1000 ppm full scale.

Table 26 is a summary of daily calibrations and maintenance notes. The excellent stability is shown by the almost negligible span drift during the times not affected by the valve malfunction. The instrument has an automatic zero that sets the baseline every five minute cycle thereby eliminating any zero drift.

5.5.5 Beckman NDIR (Model 865)

The Beckman 865 had several problems in the field. From the beginning of the field program, difficulties with the source balance on this instrument were resulting in negative deflections with CO concentrations less than 100 ppm while responses to higher concentrations were non-linear.

Although the sources were brought into balance by Scott personnel on two occasions early in the program, the sources would rapidly drift out of balance.

Significant zero and span drifts necessitated frequent adjustments. Increases in gain, compensating for span drifts, resulted in maximum gain control towards the end of December and proper span responses could not be maintained.

On January 5, a Beckman service representative was called in at which time the temperature control circuit board and detector were replaced. The instrument performed well afterward with the exception of minor zero and span drift.

Table 27 is the calibration and maintenance log for the Beckman 865.

This table illustrates the zero and span drift problems apparently resulting from the temperature controller and detector being faulty from the beginning of the program. The temperature controller and detector are principle components in an NDIR and the fact that they could be faulty without the obvious need for service illustrates the need for regular service by the manufacturer to insure reliable data.

TABLE 26. BECKMAN 6800

CALIBRATION AND MAINTENANCE

Date	Time	Span (650 ppm)	Span Drift (% Full Scale)	Maintenance Notes
12/1	1300	65.1		
12/2	1130	65.6	+0.3	
12/3	1300	65.9	+0.3	
12/4	1230	66.1	+0.4	
12/5	1100	65.3	-1.0	
12/6	1100	65.1	0	Replaced Carrier Air Cyl.
12/7	1200	66.1	+1.0	
12/8	1130	66.5	+0.2	
12/9	1230	65.3	-1.2	
12/10	1200	64.1	-1.0	
12/11	1530	64.1	+1.0	
12/12	1400	64.1	0	
12/13	1705	64.1	0	
12/14	1200	65.1	+1.0	
12/15	1108	63.1	-2.0	Replaced H_2 Cyl. @ 1200
12/16	1300	63.1	-	Replaced H_2 Cyl. due to Leaky Regulator Valve
12/17	1800	63.1	0	
12/18	1200	63.1	0	
12/19	1345	66.8	+3.5	
12/20	1400	64.1	-2.5	
12/21	1215	64.1	0	
12/22	1145	63.1	-1.0	
12/23	1230			Adjust Slope
12/24	1045	66.8	+3.5	
12/25		NO ROUTINE VISIT		
12/26	330	63.8	-3.0	
12/27		NO ROUTINE VISIT		
12/28	1315	66.1	+2.5	
12/29	1215	67.1	+0.8	
12/30	1115	67.3	+0.2	
12/31	1110	64.1	-3.0	

TABLE 26 (CONT'D) BECKMAN 6800

CALIBRATION AND MAINTENANCE

Date	Time	Span (850 ppm)	Span Drift (% Full Scale)	Maintenance Notes
1/1		NO ROUTINE VISIT		
1/2	1110	68.3	+4.0	
1/3		NO ROUTINE VISIT		
1/4	1430	67.3-74.3	-1.0 - +6.0	
1/5	1305	75.8	+8.1 - +1.5	Erratic Cal. Flow Slider Valve Problem
1/6	1200	75.8	0	
1/7	1200	85.3	+9.5	Flame Out, No Data 0100-2400
1/8	1245	69.3	-1.6	Flame Out
1/9	1248	70.3	+1	Flame Out, No Data 0000-1300, 1700-2400
1/10		NO ROUTINE VISIT		Flame Out, No Data All Day
1/11	1125	67.8	-2.5	Flame Out, No Data
1/12	1130	68.3	-0.5	Flame Out, No Data
1/13	1110	71	+2.7	Flame Out, No Data
1/14	1120	68.3	-2.7	Flame Out, No Data 0000-1200
1/15	1040	71.3	+3.0	
1/16	1100	69.3	-2.0	Erratic Cal. Flow, Slider Valve Problem Flame Out 1400-2400
1/17	1025	59.3	-10.0	Flame Out, No Data
1/18		NO ROUTINE VISIT		Flame Out
1/19	1300	64.3	+5.0	Flame Out 0000-1300
1/20	1300	63.3	-1.0	Not Responding Well, Flame Out 0700-2400
1/21	1125	66.3	+3.0	Beckman Rebuilt Faulty Valve
1/22	1200	66.5	+0.2	Working Well
1/23	1610	67.3	+0.8	Working Well

NOTE: Zero readings maintained at 5.0-6.0 chart units by automatic zero mechanism.

Span drifts based on 0-1000 ppm full scale.

TABLE 27. BECKMAN 865

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
12/1	1300	4		69.5		
12/2	1130	-2/5.5*	-6	65/69.5*	-4.5	Zero Adjust Control At Maximum
12/3	1300	12.5/7*	+7	51/70.5*	-18.5	Adjustment Of Source Balance
12/4	1230	8.2	+1.2	63.0	-6.7	
12/5	1000	8.5	+3.3	61.5	-2.3	
12/6	1100	7.0	-1.0	57.5	-4.0	Negative Response to Low Concentration
12/7	1200	14.2	+6.7	49.8	-7.7	
12/8	1130	8/7*	-6.2	55/69.5*	+5.2	Adjustment Of Source Balance
12/9	1230	10	+1	69	-0.5	
12/10	1200	11	+1	65.2	-3.8	
12/11	1530	-1	-12	63	-2.2	
12/12	1400	-1/10*	-	58/66*	-5.0	
12/13	1705	5	-5	63	-1	
12/14	1200	3.5	-1.5	65	+2	
12/15	1108	5.8/6*	2.3	63.7/70*	-1.3	Routine Cal. Adj.
12/16	1300	7	+1	67	-3.0	
12/17	1800	7	0	69	+2.0	
12/18	1200	5	-2	71	+2.0	
12/19	1345	7.5	+2.5	64.5	-6.5	
12/20	1400	20	+12.5	71.5	+7.0	
12/21	1215	12/10*	+12	68/73	-3.5	Adjust Zero
12/22	1145	10	0	71.5	+1.5	
12/23	1230	10.5	+0.5	70.3	-1.2	
12/24	1045	16/10*	+5.5	69.8/71.5*	-0.5	Adjust Zero
12/25		NO ROUTINE VISIT				
12/26	1230	11	+1	65.5	-6.0	
12/27		NO ROUTINE VISIT				
12/28	1315	21	+10	66.5	+1.0	
12/29	1215	22/1*	+11	66.8/67.2*	+0.3	Adjust Zero
12/30	1115	13.2	+2.2	68	+0.8	
12/31	1110	15.2	+2.0	64	-4.0	

TABLE 37 (CONT'D) BECKMAN 865

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
1/1			NO ROUTINE VISIT			
1/2	1110	18.5	+3.3	68.5	+4.5	
1/3			NO ROUTINE VISIT			
1/4	1430	19.5	+1	68.5	0	
1/5	1305	-/10*		-/73*		Beckman Replaced Temp. Controller And Detector
1/6	1200	7.2/7.5*	-2.8	66.1/72.7*	-6.7	
1/7	1200	5.5	-3.6	69.5	-3.2	
1/8	1245	5.7	+0.2	62.8	-6.7	
1/9	1248	5	-0.7	71	+8.2	
1/10			NO ROUTINE VISIT			
1/11	1125	1.5	-3.5	64.5	-6.5	
1/12	1230	1.2	-0.3	63.5	-1.0	
1/13	1110	0/4*	-1.2	61.8/73*	-1.7	Adj. Both Zero And Span
1/14	1120	3	+3	70	-3.0	
1/15	1040	4	+1	73	+3.0	
1/16	1100	2.5	-1.5	71.5	-1.5	
1/17	1025	1.4	-1.1	67.5	-4.0	
1/18			NO ROUTINE VISIT			
1/19	1300	0.7	-0.7	69.3	+1.8	
1/20	1300	0.2	-0.5	67.8	-1.5	
1/21	1125	0.4/14.2*	+0.2	63.6/80*	-4.2	Adjust Zero
1/22	1200	12.8	-1.4	61.7	+1.7	
1/23	1610	12.2	-0.6	60.8	-0.9	

* Adjustment Made

NOTE: Zero and span based on 1000 ppm full scale.

6.4.3 Horiba NDIR (Model AIA-2, 12/1-12/19; Model AIA-21AS, 12/19-1/21)

The original Horiba NDIR (Model AIA-2) was replaced with a newer model (AIA-21AS) on December 19 because the newer instrument is claimed to have negligible CO_2 and H_2O interference. Performance comparisons between the two instruments can be seen both in the lab evaluation results and in the field data summary.

Both Horiba instruments performed very well in the field. There had been no malfunction or lost data throughout the field or lab programs with either Horiba instrument. Both have exhibited very good zero and span stability requiring only a few routine calibration adjustments.

Table 38 is the daily calibration and maintenance log for the Horiba instruments. This table shows that except for warm-up periods at the program start and when the new Horiba NDIR was installed, both zero and span drifts were very low.

6.5 ANCILLARY INSTRUMENTATION

6.5.1 Mine Safety Appliances (NDIR) CO_2 Monitor

The MSA monitor was included in the program in order to continuously record levels of CO_2 as an interferent. Four of the five instruments under evaluation were susceptible to CO_2 interference.

The MSA instrument ran continuously for the entire program without malfunction or resultant lost data. Continuous CO_2 data is included in the field data summary.

In addition to a record of CO_2 for interference purposes, the MSA monitor proved invaluable in isolating small leaks in the sample delivery system.

6.5.2 Fyrite CO_2 Measurement

Levels of CO_2 in the duct at the sampling ports were checked periodically using a Fyrite. A Fyrite operates on the same principle as an Orsat in that the specific gas is absorbed in a chemical solution indicating the proportion of that gas in the sample.

These checks were also useful in isolating leaks in the sampling system.

TABLE 28. HORIBA INSTRUMENTS

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
12/1	1300	7		67.5		
12/2	1130	0/6*	-7	56/66.2*	-11.5	Zero Adjust
12/3	1300	4.5	-1.5	64.5	-2.3	
12/4	1210	7	+2.5	66.5	+2.0	
12/5	1100	9.7	+2.7	68.3	+1.8	
12/6	1100	9	-0.7	67	-1.3	
12/7	1200	8	-1.0	68	+1.0	
12/8	1130	7.5/4.3	-0.5	67.7/68.2*	-0.3	Zero Adjust
12/9	1230	2.8	-1.7	63.7	-4.5	
12/10	1200	3	+0.3	63.2	-0.5	
12/11	1530	7	+4.0	70	+6.8	
12/12	1400	7	0	70	0	
12/13	1705	6.5	-0.5	69.5	-0.5	
12/14	1200	6	-0.5	69	-0.5	
12/15	1108	6/6*	0	69/66.5*	0	Span Adjust
12/16	1300	6	0	66	-0.5	
12/17	1800	6	0	67	+1.0	
12/18	1200	6	0	66	-1.0	
12/19	1345	5/6.7*	-1.0	65/75.3*	-1.0	Horiba Model AIA-21AS Installed
12/20	1400	5.5	-1.2	69.5	-5.8	
12/21	1215	5.5	0	69.5	0	
12/22	1145	5/6*	-0.5	68/75*	-1.5	Span Adjust
12/23	1230	5	-1.0	75.5	+0.5	
12/24	1045	5	0	76.5	+1.0	
12/25			NO ROUTINE VISIT			
12/26	1230	5.5	+0.5	74.5	-2.0	
12/27			NO ROUTINE VISIT			
12/28	1315	4.5	-1.0	74	-0.5	
12/29	1215	4	-0.5	73.5	-0.5	
12/30	1115	4/4	0	71.8/83	-1.7	Span Adjust
12/31	1110	3.6	-0.4	77.4	-5.6	

TABLE 3A (CONT'D) HORIBA INSTRUMENTS

CALIBRATION AND MAINTENANCE

Date	Time	Zero (Chart Units)	Zero Drift (% of Full Scale)	Span (Chart Units)	Span Drift (% of Full Scale)	Maintenance Notes
1/1			NO ROUTINE VISIT			
1/2	1110	1	-0.6	75	-2.4	
1/3			NO ROUTINE VISIT			
1/4	1430	1	0	75	0	
1/5	1305	2.5	-0.5	76	+1.0	
1/6	1200	2.3	0	78	+3.0	
1/7	1200	2.6	+0.1	75.6	-2.4	
1/8	1345	2.0	-0.6	76.5	+0.9	
1/9	1248	3.0	+1.0	79	+2.5	
1/10			NO ROUTINE VISIT			
1/11	1125	2.0	-1.0	77.9	-1.1	
1/12	1230	1.6	-0.4	76.3	-1.6	
1/13	1110	1.0	-0.6	76.5	+0.2	
1/14	1120	1.0	0	76	-0.5	
1/15	1040	0.8	-0.2	75.2	-0.8	
1/16	1120	0.2	-0.6	74	-1.2	
1/17	1025	0.4	+0.2	74.4	+0.4	
1/18			NO DATA			
1/19	1300	0.2	-0.2	76.3	+1.9	
1/20	1300	0.3	+0.1	25.7	-0.6	
1/21	1125	0.5	+0.2	71.5	-4.2	
1/22	1200	0	-0.5	72.5	+1.0	
1/23	1610	0.2	+0.2	72.5	0	

* Adjustment Made

NOTE: Zero and span based on 1000 ppm full scale.

5.5.3 Flow Measuring Equipment

Duct flow rates were determined periodically using a calibrated type "S" pitot tube and magnehelic differential pressure gauge. Temperatures were measured with chrome-alumel thermocouple and pyrometer.

5.5.4 Moisture Determination Equipment

Moisture levels were usually determined twice weekly in the stack and daily in the instrument trailer. Equipment used at the stack consisted of a stainless steel probe, pre-weighed silica gel tube, calibrated dry test meter and sample pump. Equipment used in the trailer was identical with the exception that a pump was unnecessary because the sample was under pressure at this point.

Moisture data is included with the field data summary.

6.6 DATA LOGGER TRANSLATION

Each Westinghouse data logger contained two data channels and one time channel. The circuitry converted the output voltage of each analyzer to a continuous record of data pulses. Translation of these pulses into parts per million carbon monoxide was done by computer, utilising two factors which had to be calculated and entered into the tape translation program. These factors are referred to as "multiplier" and "zero adjust" factors.

Multiplier factors were used to convert raw pulses to ppm. These factors are equal to the range of the instrument in ppm divided by the range of the data logger which was 1500 pulses per 15 minute interval. Zero adjust factors allow for a positive voltage output from the instrument equalling 0 ppm CO to be translated as 0 ppm rather than some value analogous to the pulse rate for that positive voltage. This condition was maintained in order to record negative zero drifts. These zero adjust factors would then be a function of the 0 ppm instrument output and the multiplier factor.

Due to instrument drift affecting the full scale range of each instrument, these values were computed daily based on each day's span results. Therefore, span or zero drifts occurring after the entrance of multiplier and zero adjust factors was not compensated for until the next day's factors were entered. The most accurate data comparisons can therefore be made shortly after the entrance of new zero and multiplier factors.

All logger data presented is based on an average of the last three quarters of every hour. This was necessary because during the first quarter of every hour the sampling system automatically routed nitrogen zero gas to each instrument for 3 minutes. The first quarterly segment is, therefore, biased because 3 minutes of zero were included in that quarter's average.

In making data comparisons, it is also important to note that data logger translation was based on daily instrument responses to calibration with 650 ppm CO. Based on this single point, the computer translates all data over the 0-1000 ppm range linearly. Therefore, non-linearity in an instrument's calibration curve is not accounted for. This is illustrated by the typical NDIR calibration curve shown in Figure 15. This discrepancy could have been minimized by using linearizing circuits which are available as optional accessories for both NDIRs in the program.

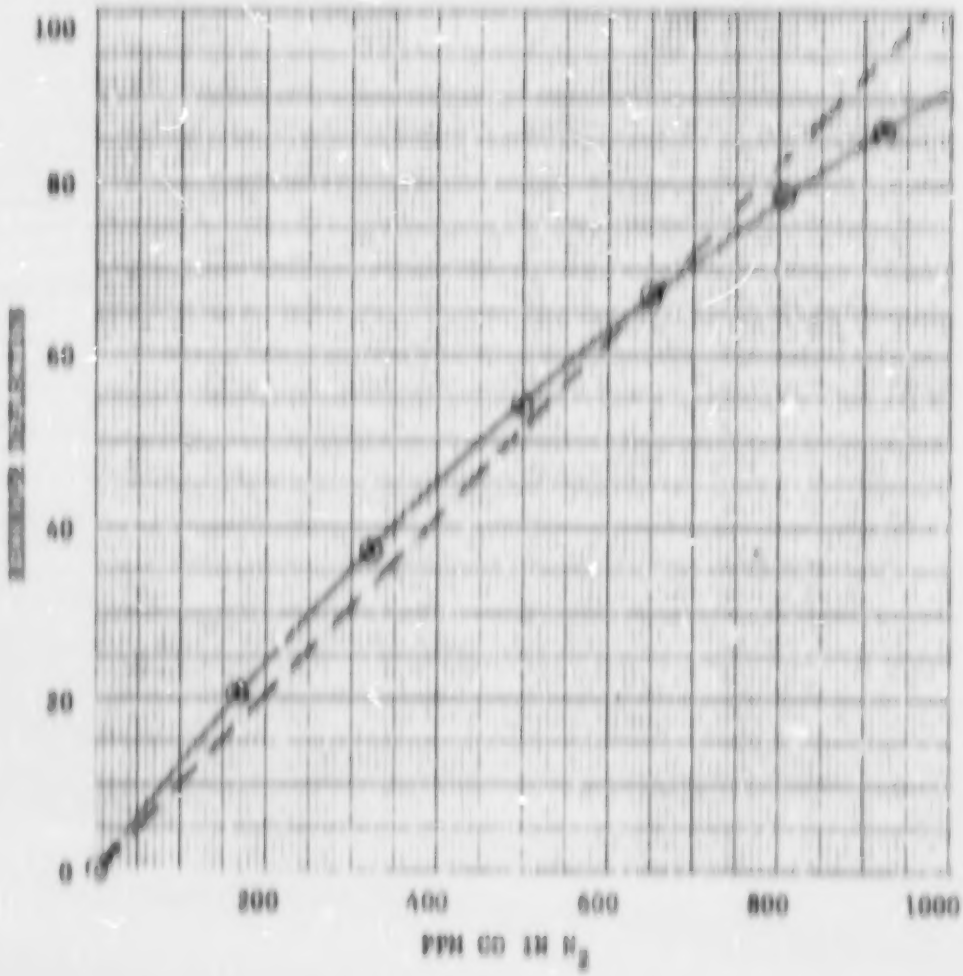

FIGURE 15 BECKMAN 865 CALIBRATION CURVE

6.7 FIELD DATA SUMMARY

The following data summary sheets contain hourly averages of the continuous field data for each instrument in the program. In addition, a continuous record of CO_2 levels and all ancillary data collected including sample and duct moistures, duct flows, temperatures and pressures and sample and process upset notes are presented.

Data for the Beckman 6800 and MSA CO_2 monitors were read from continuous strip charts. The Horiba NDIR, Beckman NDIR, ERT and Ecolyzer data were obtained from two Westinghouse data loggers. The ERT and Horiba NDIR were on one logger and the Ecolyzer and Beckman NDIR were on the other. Each logger could record a month of data on a tape cartridge. Tape cartridges were installed on December 1 and on December 31. Each tape also had a time channel that received a pulse every 15 minutes. The time coordination of these loggers remained within one 15-minute segment throughout the program.

[illegible]

[illegible]

Date: [illegible] Test Temperature: [illegible]°F Barometric Pressure: [illegible]
Sample Volume: [illegible] Ambient Temperature: [illegible]°F

Run Timing	SEC	Analyzer	Methane (ppm)	Ethane (ppm)	Propane (ppm)	CO_2 (%)	Sample* Delivery Interruption	Process ** Upset Cause
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]								
[illegible]						13-245		
[illegible]	0		539	575	629	6.18		
[illegible]	0		547	582	617	5.79		
[illegible]	0		511	545	581	5.55		
[illegible]	0		511	551	584	5.59		
[illegible]	0		505	542	576	5.55		
[illegible]	0		538	566	594	5.62		
[illegible]	0		526	560	591	5.56		
[illegible]	0		534	562	588	5.59		
[illegible]	0		504	542	576	5.55		
[illegible]	0		521	572	574	5.57		

Note: Baseline calibration times are underlined.

Run Time Lockin: [illegible]
Run Recovery: [illegible]

* Sample Delivery Notes: (Does not apply to SEC)
0 = Known Sample Mix
1 = Leak in System; Missed Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = GC Tailing Down
2 = GC Tailing Down
3 = GC Tailing Flow Diverted From Sample Rack

[redacted]

Date: [redacted] Reactor Temperature: [redacted]°F Atmospheric Pressure: [redacted]
Sample Rotation: [redacted] Ambient Temperature: [redacted]°F

Run Setting	SRT	Analyzer	Neutron #001	Neutron #002	Neutron #003	H_2	Sample Delivery Interruption	Process * Upset Event
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Note: [redacted]

* Sample Delivery Status: 0 = Normal Sample Line
(Does not apply to SRT) 1 = Leak in System; Diluted Sample
2 = Other Sample Line Interruptions

** Process Upset Status: 1 = [redacted]
2 = [redacted]
3 = [redacted]

Run Flow Index: [redacted]
Run Number: [redacted]

[illegible]

[illegible]

Date: [illegible] Boiler Temperature: [illegible]°F Barometric Pressure: [illegible]
Sample Rotameter: [illegible] Ambient Temperature: [illegible]°F

Run Reading	SEC	Analyzer	Inches H2O	Inches H2O	Inches H2O	Min O2 %	Sample Delivery Interruption *	Process Upset ** Upset Notes
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		3
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]								
[illegible]								
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

Note: Reactive calibration times are underlined.

Duct Flow Inches: [illegible]
Duct Velocity: [illegible]

* Sample Delivery Notes: (does not apply to SEC)
0 = Flow at Sample Line
1 = Leak in System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = 0% Boiler Load
2 = 0% Boiler Load
3 = 0% Boiler Flow Observed
Post Sample Test

[illegible]

Date: 12/6/75 Boiler Temperature: 60° Barometric Pressure: 30.17
Sample Volume: – Ambient Temperature: 45°

Time During	SEC	Analyzer	Reactor 6800	Reactor 6825	Burner 7010	NO_x CO_2	Sample* Delivery Interruption	Pressure** Sensor Drops
1135	0	481	403	406	551	13-142		
1140	0	459	423	396	496			
1145	0	441	423	388	489			
1150	0	442	403	387	485			
1155	0	443	403	388	488			
1200	0	466	423	396	496			
1205	0	482	423	389	478			
1210	0	505	403	426	534			
1215	0	503	443	439	538			
1220	0	513	423	427	541			
1225	0							
1230	0							
1235	0							
1240	0	472	385	339	444			
1245	0	354	244	275	378			
1250	0	767	544	485	547			
1255	0	335	274	244	365			
1300	0	333	283	244	362			
1305	0	337	275	255	376			
1310	0	325	264	240	370			
1315	0	342	273	261	381			
1320	0	360	274	268	378			
1325	0	333	263	267	368			
1330	0	260	215	188	325			

Note: Reaction calibration times are underlined.

Burr Time (orifice): –
Burr Pulsator: –

* Sample Delivery Notes: F = Process Sample Line
(does not apply to ZEC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Pressure Sensor Notes: 1 = 21 Boiler Zone
2 = 4C Boiler Zone
3 = 4C Boiler Flue Downcomer
Duct Sample Port

[redacted]

Date: [redacted] Ambient Temperature: – Barometric Pressure: [redacted]
Sample Volumes: – Ambient Temperature: [redacted]

Test Setting	SEC	Analyzer	Reactor NO_x	Reactor NO_2	Reactor NO_x	Rxn O_3	Sample Delivery Sys.	Process Sync
[redacted]	0	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[illegible]

Date: [illegible] Reactor Temperature: [illegible]°F Barometric Pressure: [illegible]
Sample Moisture: [illegible] Ambient Temperature: [illegible]°F

Run Time/Log	EHC	Analyzer	Reactor 4000	Reactor 8000	Reactor 8000	CO_2	Sample* Delivery Interruption	Process** Upset Notes
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	13-[illegible]		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			2C
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0							
[illegible]	0							
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	C	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	-		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	22		
[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]	22		*

Note: Reactor calibration times are underlined.

Duct Flow (actual): [illegible]
Duct Moisture: [illegible]

* Sample Delivery Notes: F = Fluctuating Sample Flow
(does not apply to EHC) I = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = [illegible] Spike
2 = [illegible] Spike
3 = [illegible] Flow Reversal
from Sample Duct

[redacted]

[redacted]

[redacted]

Shot Desig	SEC	Analyzer	Backscat 6800	Backscat 8020	Backscat 8020	SO_2	Sample* Delivery Interruption	Process ** Upset Error
0000	0	242	96	283	104	128		00
0030	0	284	96	307	128			
0100	0	306	136	329	155			
0130	0	330	126	363	178			
0200	0	355	146	390	201			
0230	0	372	206	317	209			
0300	0	371	323	423	293			
0330	0	250	185	286	178			
0400	0	263	243	298	196			
0430	0	274	223	305	207			
0500	0	272	243	289	199			
0530	0	258	217	297	206			
0600								
0630	251	210	226	313	209			
0700	238	217	217	287	231			
0730	304	303	417	491	321	12=348		
0800	235	371	427	355	348			
0830	484	470	357	441	46			
0900	406	2475	307	483	355			
0930	241	951	267	291	316			
1000	394	647	307	337	241			
1030	79	522	177	315	214			
1100	38	488	177	340	223			
1130	69	426	247	334	289			

Note: Reactive calibration times are underlined.

Duct Flow (scfm): 171,815
Duct Moisture: 9.2%

* Sample Delivery Notes: F = Process Sample Line
(does not apply to SEC) 1 = Leak in System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes: 1 = SO_2 Scrubber Down
2 = SO_2 Scrubber Down
3 = SO_2 Scrubber Flow Diverted From Sample Duct

[redacted]

[redacted]: [redacted] [redacted]: [redacted]°F [redacted]: [redacted]
[redacted]: [redacted] [redacted]: [redacted]°F

Run/ Evening	SSC	Analyzer	Reactor SiO_2	Reactor NO_3	Reactor SiO_2	NO_3 SiO_2	Sample* Delivery Interruption	Process ** Upset Noted
[redacted]	59	486	346	335	384	13-345		
[redacted]	60	367	337	337	179			
[redacted]	60	372	137	331	175			
[redacted]	134	362	337	334	173			
[redacted]	167	358	347	331	197			
[redacted]	177	371	347	331	179			
[redacted]	134	397	337	316	362			
[redacted]	167	383	337	384	168			32
[redacted]	375	756	347	335	381			
[redacted]	377	693	367	331	354			
[redacted]	341	823	357	389	355			
[redacted]								
[redacted]	184	383	193	331	413	13		
[redacted]	149	193	340	333	338	11		
[redacted]	180	334	397	729	383	11		
[redacted]	359	258	253	384	429	11		
[redacted]	313	338	253	396	313	13-345		
[redacted]	484	485	396	538	616			
[redacted]	760	634	503	331	649			2
[redacted]	638	262	486	429	367			
[redacted]	691	849	389	382	684			
[redacted]	634	577	333	544	688			4
[redacted]	713	894	386	437	784			32
[redacted]	439	340	359	433	333			4

Note: Reactive calibration times are underlined.

[redacted]: [redacted]
[redacted]: [redacted]

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to SSC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = [redacted]
2 = [redacted]
3 = [redacted]
[redacted]

[redacted]

Date: [redacted] Thaller Temperature: [redacted]°F Barometric Pressure: [redacted]
Sample Moisture: [redacted] Ambient Temperature: [redacted]°F

Run Setting	SRC	Analyzer	Reactor 4863	Reactor 4859	Reactor 4858	CO_2	Sample* Delivery Interruption	Process ** Upset Notes
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		

Note: Reactor calibration times are underlined.

Dust Flow (scfh): [redacted]
Dust Moisture: [redacted]

* Sample Delivery Notes: F = Stream Sample Flow
(Does not apply to SRC) I = Link to Systems Delayed Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #1 Boiler Flow Diverted
From Sample Duct

[redacted]

Date: [redacted] Reactor Temperature: [redacted]°F Barometric Pressure: [redacted]
Sample Moisture: - Ambient Temperature: [redacted]°F

Run Desig	SRC	Analyses	Reactor (SRC)	Reactor (Ash)	Burner (Ash)	SO_2 $lb/10^6$ Btu	Sample* Delivery Interruptions	Process ** Upset Hours
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]		

Note: Reactor calibration times are underlined.

Dust Flow (wt%): -
Dust Moisture: -

* Sample Delivery Codes: F = Frozen Sample Line
(Does not apply to SRC) L = Leak in System, Nonrepresentative Sample
I = Other Sample Flow Interruptions

** Process Upset Codes: 1 = [redacted]
2 = [redacted]
3 = [redacted] Flow Diverted From Sample Port

DATA REPORT
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 10/24/73 Analyzer Temperature: 80°F Barometric Pressure: 30.44
Sample Rotameter: - Ambient Temperature: 65°F

Run Timing	SRC	Analyzer	Reactor 6007	Reactor 6019	Burette 6020	NDIR CO_2	Sample* Delivery Interruption	Process** Upset Notes
1300	62	490	527	559	571	13-162		
1315	62	467	500	538	571			
1330	62	445	496	529	570			
1345	62	441	496	535	570			
1400	64	429	500	539	570			
1415	64	423	496	534	570			
1430	62	408	504	534	570			
1445	62	405	506	530	570			
1500	56	394	528	538	570			
1515	56	373	506	538	570			
1530	57	368	498	527	571			
1545								
1600								
1615	55	368	422	471	585			
1630	55	357	423	470	570			
1645	55	351	421	467	570			
1700	54	334	421	470	570			
1715	55	334	421	471	571			
1730	55	328	441	482	570			
1745	54	321	441	484	570			
1800	54	308	441	485	570			
1815	54	292	441	485	570			
1830	54	282	441	485	570			

Note: Reactor calibration curve was substituted.

Duct Flow (scfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Process Sample Line
(does not apply to SRC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted
From Sample Duct

DATA SUMMARY
FINAL EVALUATION OF CARBON MONOXIDE MONITORS

Date: [illegible] Detector Temperature: [illegible]°F Barometric Pressure: 29.97
Sample Rotameter: 8.5SR Ambient Temperature: 47°

Run Testing	CMC	Analyzer	Reference (ppm)	Reference (ppm)	Corrected (ppm)	CO_2 %	Sample* Delivery Interruptions	Process** Upset Runs
[illegible]	46	439	353	430	448	13-14%		
[illegible]	4	441	343	434	454			
[illegible]	4	433	353	443	448			
[illegible]	4	432	348	442	437			
[illegible]	138	435	344	445	441			
[illegible]	241	435	351	443	441			
[illegible]	240	448	371	438	454			
[illegible]	134	454	353	432	438			
[illegible]	239	464	374	438	469			
[illegible]	241	466	364	427	458			
[illegible]	178	428	333	429	436			
[illegible]	239	462	354	432	444			
[illegible]								
[illegible]	272	398	337	447	413	9+ Lbs		
[illegible]	239	397	355	434	434			
[illegible]	241	402	365	434	442			
[illegible]	236	406	369	439	449			
[illegible]	136	414	377	455	471			
[illegible]	60	425	368	439	442			
[illegible]	74	424	369	440	443			
[illegible]	243	425	388	475	464			
[illegible]	277	434	420	496	488			
[illegible]	240	444	402	388	334			

Note: Baseline calibration times are underlined.

Duct Flow (scfm): 151,700
Duct Moisture: 8.5%

* Sample Delivery Notes: F = Process Sample Line
(does not apply to CMC) L = Leak in System, Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = 02 Meter Down
2 = 02 Probe Down
3 = 02 Meter Flow Reversed
From Sample Duct

[redacted]

Date: [redacted] Injector Temperature: [redacted]°F Barometric Pressure: [redacted] in Hg

Sample Rotameter: - Ambient Temperature: [redacted]°F

Run Serial	HRC	Analyzer	Incident NO_x	Incident SO_2	Burner Rate	NO_x O_2	Sample* Delivery Interruption	Process ** Upset Notes
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	No Loss		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	134-145		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			

Note: Precise calibration times are underlined.

Duct Flow (scfm): -

Duct Moisture: -

* Sample Delivery Notes: (does not apply to HRC)
0 = Process Sample Line
1 = Leak in System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = SO2 Boiler Down
2 = SO2 Boiler Down
3 = SO2 Boiler Flue Diverted From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/20/75 Tracer Temperature: 68°
Sample Rotameter: -

Barometric Pressure: 30.23
Ambient Temperature: 58°

Run Timing	EMC	Analyzer	Rotameter 6000	Rotameter 3000	Bottle 2000	CO_2	Sample* Delivery Interrogation	Pressure ** Tracer Valve
1510	625	594	532	534	605	13-142		
1538	651	621	623	605	662			
1610	620	594	623	531	677			
1640	629	560	623	609	679			
1708	623	57[illegible]	592	588	651			
1733	608	557	592	571	617			
1756	631	601	603	570	636			
1823	639	568	623	594	663			
1848	621	634		568	676			
1910	659	617		588	642			
1936	647	603		594	663			
2000	64	626		537	643			
2030								
2048								
2110	64	601	544	595	643			
2147	642	711	551	605	588			
2210	642	729	583	607	597			
2240	651	64[illegible]	592	471	591			
2306	570	58	563	385	651	86		22
2335	240			54	3			
2355	365			63	3			
0015	544	2	534	69	3			
0040	74		485	64	34			
0105	60	106	560	582	609	136		-

Note: Rotameter calibration values are underlined.

Duct Flow (actual): -
Duct Velocity: -

* Sample Delivery Notes: 0 = Present Sample Line
(Does not apply to EMC) 1 = Lost in System; Delayed Sample
2 = Other Sample Flow Interrogations

** Pressure Tracer Notes: 1 = EC Tracer Down
2 = CO Tracer Down
3 = EC Tracer Flow Diverted
From Sample Duct

DATA SET: [illegible]
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/28/75 Boiler Temperature: 72° Barometric Pressure: 30.31
Sample Moisture: - Ambient Temperature: 24°

Run Setting	SRC	Analyzer	Bacharach 9600	Bacharach 9512	Bacharach 9503	MSA CO_2	Sample* Delivery Interruptions	Process ** Upset Notes
[illegible]	334	+30		81	7	08		02
[illegible]	347	+32		83	6			
[illegible]	445	+34		87	6			
[illegible]	432	+35		92	4			
[illegible]	398	+36		108	4			
[illegible]	356	+37		106	4			
[illegible]	333	+38		111	3			
[illegible]	346	+39	514	128	3			
[illegible]	542	01	495	396	429	135		
[illegible]	511	24	514	435	339	0-135		
[illegible]	446	335	514	392	422	13-145		
[illegible]	354	401	474	767	349			
[illegible]	335	682		783	345			
[illegible]	379	548		591	547	-		
[illegible]	31	57		6	17	08		
[illegible]	29	-		5	14			
[illegible]	28	-		11	14			
[illegible]	29	-		17	15			
[illegible]	31	-		24	13			
[illegible]	31	-		29	16			
[illegible]	43	-		33	17			
[illegible]	48	-		38	17			
[illegible]	41	-		47	18	-		

Note: Bacharach calibration times are underlined.

Duct Flow (scfh): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to SRC)
0 = Proper Sample Line
1 = Leak in System, Diluted Sample
2 = Other Sample Flow Interruption

** Process Upset Notes:
1 = 4% Boiler Load
2 = 4% Boiler Load
3 = 4% Boiler Flow Diverted From Sample Duct

[illegible]

[illegible]

Date: [illegible] Boiler Temperature: [illegible]°F Barometric Pressure: [illegible]
Sample Resistance: - Ambient Temperature: [illegible]°F

Run Timing	SMT	Analyzer	Nitrous Oxide (N2O)	Propane (C3H8)	Butane (C4H10)	TOA (C4H10)	Sample* Delivery Interruptions	Process ** Upset Status
[illegible]	28	-		47	26	[illegible]		NO
[illegible]	46	-		54	29			
[illegible]	42	-		60	29			
[illegible]	29	-		65	29			
[illegible]	26	-		70	27			
[illegible]	357	-		74	26			
[illegible]	30	-		53	25			
[illegible]	31	-		85	23			
[illegible]	427	-		88	24			
[illegible]	46	-		93	23			
[illegible]	461	-		97	23			
[illegible]	447	50		333	241	-		
[illegible]						23-248		*
[illegible]	393	423	355	391	445			
[illegible]	385	387	335	378	433			
[illegible]	369	343	315	346	424			
[illegible]	417	339	333	381	434			
[illegible]	418	373	378	417	483			
[illegible]	425	381	379	425	485			
[illegible]	477	368	346	422	478			
[illegible]	339	324	347	376	449			
[illegible]	338	392	335	359	431			
[illegible]	376	375	325	350	429			
[illegible]	384	338	332	343	421			

Note: Reactive calibration times are underlined.

Duct Flow (scfm): -
Duct Moisture: -

* Sample Delivery Notes: 0 = Process Sample Line
(does not apply to SMT) 1 = Leak in System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes: 1 = [illegible]
2 = [illegible]
3 = [illegible] Flow Reversed
From Sample Duct

DATA SUMMARY

FIELD TRANSFER OF GASEOUS REFERENCE MIXTURES

Date: 10/20/75 Nozzle Temperature: 70° Barometric Pressure: 29.83

Sample Resistance: - Ambient Temperature: 28°

Run Number	SRC	Analyzer	Reference #897	Reference #813	Service #819	Mole O_2	Sample* Delivery Interruption	Process** Upset Notes
0200	340	250	315	348	473	13-14%		
0210	348	246	325	356	434			
0220	336	230	326	355	445			
0230	431	215	425	457	496			
0240	422	256	405	437	531			22
0250	388	227	366	404	477			
0300	365	226	366	391	464			
0310	342	245	376	392	448			
0320	381	234		405	479	12%	1	
1010	297	270		366	408	"	"	
1130	336	267		407	429			
1140								
1150								
1210	301	224		47	0			
1220	362	48		75	41	13-14%		0
1240	350	238		381	532		0	
1250	420	264	137	79	172			
1300	434	280	137	11	173			
1310	422	280	137	28	170			
1320	421	256	137	84	382			
1330	429	266	137	66	387			
1340	423	281	147	108	383			
1350	426	281	137	145	383			
2400	406	263	147	139	384			

Note: Reactive calibration times are underlined. Duct Flow (scfm): -

Duct Moisture: -

* Sample Delivery Notes: (Does not apply to SRC) 0 = Proven Sample Line
1 = Leak in System, Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes: 1 = [illegible]
2 = [illegible]
3 = [illegible] Flow Diverted From Sample Duct

[illegible]

[illegible]

Date: [illegible] Tunnel Temperature: [illegible]°F Barometric Pressure: [illegible]

Sample Pressure: [illegible] Ambient Temperature: [illegible]°F

Run Indicator	SMP	Sampler	Sample Inlet Mach Number	Sample Inlet Velocity ft/sec	Sample Inlet Reynolds Number	SO_2 ppm	Sample* Delivery Interruption	Pressure ** Sensor Noise
[illegible]	474	214	147	159	194	13-142		
[illegible]	475	214	137	165	191			
[illegible]	482	201	147	177	198			
[illegible]	467	210	147	177	192			
[illegible]	485	211	147	186	198			
[illegible]	476	208	136	188	197			
[illegible]	501	203	157	192	197			
[illegible]	504	215	147	190	196			
[illegible]	511	214	157	196	203			
[illegible]	493	207	147	201	207			
[illegible]	485	241	159	205	211			
[illegible]	486	240	147	211	211			
[illegible]								
[illegible]	247	133		147	148			
[illegible]	31	134		161	139			
[illegible]	0	249		205	195			
[illegible]	5	244		197	182			
[illegible]	74	246		196	183			
[illegible]	303	262		247	178			
[illegible]	438	233		196	171			
[illegible]	72	262		201	187			
[illegible]	131	133		159	148			
[illegible]	288	135		206	189			
[illegible]	75	262		159	226			

Note: Reverse calibration runs are underlined.

Duct Flow (actual): [illegible]

Duct Moisture: [illegible]

* Sample Delivery Notes: (Does not apply to SMP)
- T = Process Sample Loss
- L = Leak in System; Diluted Sample
- I = Other Sample Flow Interruptions

** Pressure Sensor Notes:
- 1 = #1 Boiler Loss
- 2 = #2 Boiler Loss
- R = #2 Boiler Flow Reversal From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/23/75 — Station Temperature: - — Barometric Pressure: 30.38
Sample Moisture: - — Ambient Temperature: 28°

Run Listing	SEC	Analyzer	Nucleus 6603	Nucleus 3029	Servlin 6213	MSA CO_2	Sample* Delivery Interruptions	Process ** Upset Noise
0130	355	377	334	377	399	13-142		
0230	337	376	364	371	402			
0330	427	372	294	360	398			
0430	435	376	294	372	402			
0530	422	359	304	370	399			
0630	427	382	311	377	415			
0730	360	361	304	376	414			
0830	334	379	334	376	408			
0930	361	385	334	378	410			
1030	388	385	364	375	407	-		22
1130	408	331	344	385	419	12		
1230	460	38		44	7			
1330	482	9		22	6			
1430	477	9		34	30			
1530	462	7		37	19			
1630	448	5		31	9			
1730	436	7		37	35			4
1830	423	2		42	9	-		
1930	446	394	354	397	380	13-142		
2030	404	351	305	364	352			
2130	374	371	305	385	395			
2230	373	364	295	374	384			
2330	380	372	305	387	389			
2430	374	381	295	386	392	-		

Note: Reactive calibration times are underlined.

Duct Flow (scfm): -
Duct Moisture: -

* Sample Delivery Notes: (does not apply to SEC)
0 = Process Sample Line
1 = Leak in System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = 4% Boiler Down
2 = 4% Boiler Down
3 = 4% Boiler Flow Diverted From Sample Duct

[illegible] STACK

FIELD EVALUATION OF [illegible] MONITOR MODIFIED

Date: 12/28/73 Nozzle Temperature: - Barometric Pressure: 28.75

Sample Moisture: 0.04% Ambient Temperature: 47°

Run Timing	EBC	Ex- gas	Nozzle mBTU	Nozzle SCCS	Nozzle SCCS	NOx ppm	Sample* Delivery Interruptions	Traverse ** Point Notes
0100	379	317	305	340	385	13-345		
0230	351	380	305	379	388			
0315	369	364	295	379	345			
0400	795	420	315	385	471			
0515	783	413	315	392	421			
0630	8.0	403	315	389	415			
0700	420	384	315	391	417			
0800	41	398	302	442	427			
0945	43	408	342	434	477			
1000	43	508	482	425	476			
1130	43	303	317	377	388			
1215	48	261	248	260	294			
1300								
1400	36	334	317	349	373			
1430	46	377	357	355	373			
1530	42	398	287	359	375			
1730	42	334		333	364			
1900	42	385		347	357			
2001	42	367		348	354			
2200	42	338		316	335			
2330	42	333		339	341			
2500	42	330		346	345			
2530	42	347		351	348			
2600	42	349	175	359	345			

Note: Reactive calibration times are underlined.

Duct Flow (acfm): 243,351

Duct Moisture: 10.4%

* Sample Delivery Notes: F = Process Sample Line
(Does not apply to EBC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Traverse Point Notes: 1 = #1 Boiler Zone
2 = #2 Boiler Zone
3 = #2 Boiler Flue Diverted From Sample Duct

DATA SUMMARY

FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 10/30/75 Trailer Temperature: - Barometric Pressure: 29.98

Sample Moisture: - Ambient Temperature: 37°

Test Ending	EMC	Analyzer	Jackson 6600	Jackson 6200	Horiba 6013	NDIR CO_2	Sample* Delivery Interruption	Process ** Upset Notes
0330	42	143	265	257	241	13-14%		
0730	42	151	275	263	245			
1130	42	155	274	259	275			
1430	43	158	274	262	248	"		
1500	42	147	275	273	246	No Data		
1630	42	109	264	456	243			
1930	43	69	243	253	238			
2430	42	61	235	246	231			
2830	42	64	235	234	229			
3130	42	61	234	246	227			
3330	42	102	253	263	239			
3730	48	72	254	258	251			
4130	50	61	245	256	232			
4430	46	72	245	255	243			
4730	35	87	233	251	272			
5030	41	84	235	259	254			
5330	51	96	235	256	290			
5730	49	97	230	257	280			
6030	49	77	239	256	287			
6330	50	80	235	259	288			
6730	50	49	235	250	275			
7030	48	39	225	252	285			
7330	45	36	225	255	282			
7400	43	29	235	259	287	"		

Note: Baseline calibration times are underlined.

Duct Flow (scfm): -

Duct Moisture: -

* Sample Delivery Notes: F = Process Sample Line
(does not apply to EMC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted
From Sample Duct

[illegible]
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/20/73 Stacker Temperature: -- Barometric Pressure: 30.23
Sample Moisture: -- Ambient Temperature: 72°F

Hour Ending	EMC	Analyzer	Nucleus 4800	Nucleus 8618	Horiba 8010	NDIR CO_2	Sample* Delivery Interruption	Process** Upset Hours
0100	47	21	125	234	178	No Data		
0200	43	21	119	235	171			
0300	48	15	114	231	164			
0400	49	25	125	242	175			
0500	35	25	129	237	171			
0600	37	32	134	243	168			
0700	36	26	135	246	169			
0800	38	28	134	246	167			
0900	45	21	134	247	166			
1000	42	-	134	233	167			
1100	47	1	125	234	171			
1200	48	7	129	243	165			
1300	44	34	134	249	169	-		
1400						4.26		
1500	11	69	65	96	133	0		
1600	15	54	89	129	147	20		
1700	43	48	104	111	163	12		
1800	33	36	94	115	163	12		
1900	42	42	116	137	184	No Data		
2000	33	55	119	167	186			
2100	46	56	126	156	179			
2200	50	58	129	161	177			
2300	38	58	131	161	174			
2400	29	64	130	170	178			

Note: Reactor calibration times are underlined.

Duct Flow (scfm): --
Duct Moisture: --

* Sample Delivery Notes: P = Proper Sample Line
(Does not apply to EMC) L = Leak in System; Deliver Sample
I = Other Sample Flow Interruptions

** Process Upset Hours: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flow Diverted From Sample Duct

[illegible] STREET
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 12/29/75 Trailer Temperature: 60°
Sample Tubetemp: -
Barometric Pressure: 30.40
Ambient Temperature: 34°

Hour Ending	EST	Analyzer	Maximum 8-HOUR	Maximum 1-HOUR	Maximum 30-MIN	NOx ppm_2	Sample* Delivery Interruption	Process** Upset Action
0100	22	57	120	168	176	No Lab		
0200	23	57	115	164	172			
0300	33	77	109	147	159			
0400	46	81	194	264	270			
0500	44	85	214	290	291			
0600	48	72	204	278	278			
0700	157	88	115	206	281			
0800	111	86	120	275	278			
0900	31	71	120	281	294			
1000	33	71	115	176	245			
1100	36	72	118	275	298			
1200	46	82	138	293	307			
1300	236							
1400	11							
1500	28	22	25	28	11			
1600	46	28	66	34	37			
1700	44	58	68	75	61			
1800	13	63	59	63	70			
1900	61	62	58	80	68			
2000	48	63	58	65	65			
2100	47	61	58	78	64			
2200	46	59	58	80	63			
2300	37	59	58	65	61			
2400	46	59	58	95	62			

Note: Routine calibration times are underlined.

Duct Flow (cfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Frozen Sample Line
(Does not apply to EST) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted
From Sample Duct

[illegible]

[illegible]

Date: [illegible] Probe Temperature: 76° Barometric Pressure: 30.19

Sample Moisture: 1.2% Ambient Temperature: 28°

Hour Ending	SRC	Analyzer	Reactor 6803	Reactor 6813	Scrubber 6879	NOx (ppm_v)	Sample* Delivery Interruptions	Process** Upset Notes
1100	44	56	58	90	59	No Data		
1200	45	57	59	91	61			
1300	34	59	53	89	58			
1400	32	59	55	9	57			
1500	49	58	58	97	63			
1600	28	58	56	88	61			
1700	29	58	56	101	63			
1800	25	58	58	105	60			
1900	37	57	49	86	58			
2000	4	56	56	92	59			
2100	32	53	45	88	56			
2200	34							
2300	47	76	55	85	74			
2400	48	80	65	95	79			
2500	54	86	65	94	81			
2600	4	87	65	98	83			
2700	48	87	65	104	83			
2800	48	85	65	101	80			
2900	44	55	28	53	37			
3000	48	49	25	53	37			
3100	26	45	29	47	36			
3200	3	46	25	50	39			
3300	38	44	28	52	40			
3400	38	43	28	55	41			

Note: Reactive calibration times are underlined.

Duct Flow (scfm): 131,737

Duct Moisture: -

* Sample Delivery Notes: F = Process Sample Line
(Does not apply to SRC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted From Sample Duct

[redacted]

[redacted]

Date: [redacted]

Trailer Temperature: [redacted]°F
Sample Moisture: [redacted]

Barometric Pressure: [redacted]
Ambient Temperature: [redacted]°F

Hour Ending	HRT	Analyzer	Backpack [redacted]	Enclosure [redacted]	Service [redacted]	CO_2	Sample* Delivery Interruption	Process ** Upset Notes
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	No Data		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			

Note: Routine calibration times are underlined.

Duct Flow (scfh): --
Duct Moisture: --

* Sample Delivery Notes: (does not apply to HRT)
F = Frozen Sample Line
L = Lost in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted From Sample Duct

[redacted]

[redacted]

Date: 4/21/76 Stacker Temperature: - Barometric Pressure: 29.91

Sample Numbers: - Ambient Temperature: 74°

Event Timing	Time	Analyzer	Reactor 6507	Reactor 9503	Burner 9503	NOx O_2	Sample* Delivery Interruption	Sample** Event Notes
0135	345	84	74	111	40	No Data		
0145	336	78	62	118	43			
0155	341	78	51	119	45			
0405	338	77	51	136	47			
0510	334	88	51	140	41			
0605	329	85	61	137	36			
0715	326	95	61	149	47			
0810	376	109	92	164	103			
0915	389	97	92	145	94			
1005	403	124	72	171	119			
1045	402	123	112	176	111			
1100	404	125	91	173	119			
1145	404	119	89	166	115			
1200	398	104	73	149	96			
1230	413	142	102	174	153			
1245	411	134	92	165	177			
1315	401	99	62	146	98			
1345	409	88	52	126	84			
1430	409	82	72	132	82			
1515	396	96	72	154	105			
1600	402	91	83	147	92			
1645	401	97	92	148	89			
1730	391	108	73	171	109			
1800	385	174	123	193	131			

Note: Analyzer calibration times are underlined.

Duct Flow (scfm): -

Duct Velocity: -

* Sample Delivery Notes: (Does not apply to 9503)
0 = Process Sample Line
1 = Lost to System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Event Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted From Sample Duct

FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/30/79 Stack Temperature: 60°F Barometric Pressure: 30.26

Sample Moisture: .6 Ambient Temperature: 38°F

Test Timing	EMC	Analyzer	Incinco 6600	Incinco 9823	Ecolyzer 9310	NO_x	Sample* Delivery Interruption	Process ** Upset Notes
0100	157	175	113	231	170	No Data		
0230	361	193	143	253	189			
0305	367	191	133	248	181			
0430	369	155	113	209	142			
0544	375	152	135	208	143			
0630	316	156	113	215	148		2	
0710	342	43	38	74				
0830	332	17	18	48				
0900	348	11	18	44				
1005	357	172	113	183	121			
1104	402	34	-	105	111			
1210								
1245						95	0	
1400	73	90	77	61	51		2	
1540	96	130	87	137	119			
1630	134	158	97	159	141			
1715	110	166	117	146	139			
1805	91	134	87	117	96			
1900	96	135	99	111	102			
2000	101	135	87	111	114			
2100	88	139	107	126	119			
2200	74	157	107	149	136			
2300	111	165	77	159	144			
2400	134	161	109	149	136			

Note: Reactive calibration times are underlined.

Duct Flow (scfm): 110-117

Duct Moisture: 11.6

* Sample Delivery Notes: (Does not apply to EMC)
0 = Process Sample Line
1 = Leak in System; Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #1 Boiler Flue Diverted From Sample Duct

[redacted]

Date: 2/27/76 Boiler Temperature: – Barometric Pressure: 29.98
Sample Moisture: – Ambient Temperature: 35°

Run Indicator	SRC	Analyzer:	Reactor 2800	Reactor 3000	Profile 3000	SO_2	Sample* Delivery Interruptions	Process ** Upset Notes
0100	112	257	97	147	139	92		
0230	105	148	97	135	126			
0300	105	155	108	142	139			
0430	94	142	99	147	131			
0700	88	153	98	134	135			
0830	48	164	118	135	146			
1000	31	171	147	147	162			
1030	42	172	128	96	156			
1900	4	166	118	124	148			
2000	4	170	108	100	171			
2100	14	175	127	143	159			
2200	33	154	97	126	131			
2300	57	159	77	108	126			
2400	6	162	97	113	135			
2500	35	165	86	121	145			
2600	108	167	96	121	141			
2700	119	158	106	113	133			
2800	104	160	97	104	126	2		
2900	105	139	68	95	111	78		
3000	105	132	66	84	92	65		
3100	92	107	79	67	65			
3200	82	105	58	64	59			
2300	66	100	45	49	56			
2400	60	105	36	51	58	4		

Note: Reactor calibration times are underlined.

Duct Flow (scfm): –
Duct Moisture: –

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to SRC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = 01 Boiler Down
2 = 02 Boiler Down
3 = 02 Boiler Flue Diverted
From Sample Duct

FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/6/78

Instr. Temperature: 40°
Sample Reference: –

Barometric Pressure: 30.02
Ambient Temperature: 28°

Hour Ending	EPA	Analyzer	Beckman 6800	Beckman 9832	Ecolyzer 9810	SO_2	Sample* Delivery Interruption	Process ** Upset Action
0700	87	98	40	44	47	45		
0800	99	101	40	47	49			
0900	101	107	40	57	59			
1000	103	126	50	90	88	95		
1100	73	108	60	72	58			
1200	60	104	40	65	54			
1300	56	110	40	75	58			
1400	42	108	40	53	55			
1500	47	~0	50	73	68			
1600	57	114	50	76	66			
1700	56	108	60	85	77			
1800	56	116	60	76	58			
1900	96	121	50	88	75			
2000								
2100	245	42	–	76	74	120		
2200	48	61	40	65	64			
2300	59	88	40	92	86			
2400	111	98	47	111	114			
2500	142	47	60	135	125			
2600	136	88	60	142	140			
2700	127	78	100	136	136	105		
2800	106	61	80	78	75			
2900	106	66	60	105	106			

Note: Daytime calibration times are underlined.

Duct Flow (scfm): –
Duct Reference: –

* Sample Delivery Notes: (does not apply to EPA)
P = Process Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = SO_2 Boiler Down
2 = CO Boiler Down
3 = SO_2 Boiler Flue Diverted From Scrubb Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/31/79 Trailer Temperature: 68°
Sample Moisture: -
Barometric Pressure: 30.41
Ambient Temperature: 27°

Hour Ending	EMC	Analyzer	Ambient (ppm)	Exhaust (ppm)	Exhaust (ppm)	MSA CO, %	Sample* Delivery Interruption	Process** Upset Error
0100	541	84	42	105	110	105		
0200	517	83	73	109	113			
0300	537	56	74	74	79			
0400	567	57	56	79	86			
0500	588	58	84	5-	54			
0600	61A	53	73	72	76			
0700	594	44	46	45	50			
0800	571	45	24	56	58			
0900	547	48	39	65	67			
1000	595	45	34	59	61	13-142		
1100	488	46	46	55	52			
1200	384	34	36	19	192			
1300								
1400								
1500	385	-	35	37	48		F	
1600	0	-	35	30	33			
1700	0	-	45	26	53			
1800	0	-	33	25	53			
1900	0	-	45	34	60			
2000	0	-	55	36	61			
2100	0	-	35	33	48			
2200	0	-	45	30	58			
2300	0	-	25	-	9			
2400	0	-	35	25	33		F	

Note: Analyzer calibration times are underlined.

Duct Flow (scfm): -
Duct Velocity: -

* Sample Delivery Errors: F = Process Sample Line
(Does not apply to EMC) L = Leak in System; Dilutes Sample
I = [illegible] Sample Flow Interruptions

** Process Upset Errors: 1 = [illegible]
2 = [illegible]
3 = [illegible] Flow Diverted
From Sample Duct

DATA SUMMARY
FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/31/74

Stroller Temperature: 68°
Sample Moisture: .57

Barometric Pressure: 30.49
Ambient Temperature: 24°

Hour Ending	EMC	Analyzer	Thermos 6800	Ambient 9219	Bridge 9218	NDIR CO_2	Sample* Delivery Interruption	Process** Upset Action
0100	3	-	45	34	54	23-148	F	
0200	3	-	35	31	53			
0300	29	-	35	31	59			
0400	8	-	45	35	60			
0500	9	-	45	31	57			
0600	29	-	55	36	68			
0700	30	14	45	50	80			
0800	34	23	62	37	76			
0900	37	8	55	38	76			
1000	38	34	55	42	79			
1100	42	-	-	42	75			
1200								
1300						102	F	
1400	57		36	46	45			
1500	54	77	36	48	64			
1600	62	69	36	53	55			
1700	61	104	36	54	63			
1800	70	68		47	62			
1900	72	71		33	53			
2000	74	73		55	54			
2100	75	72		50	51			
2200	64	62		40	42			
2300	68	61	36	42	48			
2400	68	59	36	42	43			

Note: Reactive calibration times are underlined.

Duct Flow (cfm): 171,329
Duct Moisture: 9.3

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to EMC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flow Diverted
From Sample Duct

DATA SUMMARY

FIELD EVALUATION OF CARBON MONOXIDE MONITORS

Date: 1/7/76 Trailer Temperature: 71° Barometric Pressure: 30.10

Sample Rotameter: - Ambient Temperature: 75°

Run Timing	EPC	Envirotec	Beckman 6800	Beckman 6800	Servomex 6400	MSA CO_2	Sample* Delivery Interruptions	Process ** Upset Notes
0100	49	41	34	45	49	No Data		
0130	43	36	Plume Out	40	42			
0200	46	38		42	44			
0230	46	32		37	43			
0300	48	40		38	38			
0400	38	46		36	38			
0500	32	42		34	40			
0530	48	43		3	35			
0600	46	43		36	34			
0630	36	43		37	32			
0700	42	45		35	36			
0730								
0800								
0830	32	46		42	37	102		
0900	33	48		39	39			
0930	45	45		34	45			
1000	33	41		35	31			
1030	39	45		38	37			
1100	49	48		42	41			
1130	38	36		38	38			
1200	35	37		31	39			
1230	45	47		40	36			
1300	45	45		38	36			
1400	46	39		30	30			

Note: Monitor calibration times are underlined.

Duct Flow (actual): -

Duct Velocity: -

* Sample Delivery Notes: F = Process Sample Line
(does not apply to EPC) L = Leak in System; Dilut. & Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #1 Boiler Flue Diverted
From Sample Duct

[illegible]

Date: 1/8/76 Nozzle Temperature: 76° Isokinetic Pressure: 29.92
Sample Velocity: .72 Ambient Temperature: 76°

Run Ending	SRT	Analyzer	Reference ΔP (mm)	Reference ΔH (mm)	Orifice ΔH (mm)	Meter ΔH, ΔH_a	Sample* Delivery Interruption	Process** Upset Noted
0330	79	92	Flame Out	36	38	Jammed		
0345	81	79		38	32			
0400	83	84		35	37			
0415	85	88		33	39			
0430	87	76		39	39			
0445	86	78		36	36			
0500	73	101		33	33			
0515	75	104		37	43			
0530	83	113		42	72			
0545	101	111		39	46			
0600	108	119		77	86			
0615	849	103		48	77			
0630			"			"		
0645								
0700	887	89	40	53	61	72		
0715	705	71	29	35	45			
0730	708	51	19	17	25	1		
0745	722	54	Flame Out	15	31	5		
0800	726	68		42	45	7		
0815	742	86		37	46	9		
0830	750	94		84	79			
0845	775	113		107	105			
0900	695	104		109	105			
0915	735	125	"	105	108	"		

Note: Reactive calibration times are underlined.

Run Flow (scfm): 132,793
Run Moisture: 5.9

* Sample Delivery Notes: (does not apply to SRT)
0 = Process Sample Line
1 = Leak in System; Dilutes Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flow Diverted From Sample Duct

[redacted]

Date: 1/9/76 Boiler Temperature: [redacted] Barometric Pressure: [redacted]
Sample Moisture: -- Ambient Temperature: [redacted]

Test Probing	SRC	Analyzer	Incinco 6020	Incinco 3010	Servomex 1010	CO_2	Sample* Delivery Interruptions	Process ** Upset Notes
0730	733	330	Flame Out	95	95	95		
1345	728	332		101	98			
0905	750	326		124	111		1	
1421	757	38		6	7			
1054	760	42		3	8			
0.60	749	40		4	6			
1300	765	38		3	5	-		
1900	764	37		3	6	88		
1336	735	37		2	7			
1115	709	37		2	7			
1100	666	38		6	8			
1340	676	39		8	10	-		
1743						2.48	2	
1745							1	
1500	101	107		85	79			
1530	130	128		105	98			
1700	120	120		98	96			
1400	111	116		91	87			
1140	109	113		87	85			
1410	110	116		87	84			
1430	116	117		87	85			
1500	111	113		91	85			
1540	105	108		90	85			
1600	115	111	"	90	86	"		

Note: Routine calibration runs are underlined.

Duct Flow (scfm): --
Duct Moisture: --

* Sample Delivery Notes: (does not apply to SRC)
F = Process Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = O_2 Boiler Trip
2 = O_2 Boiler Down
3 = O_2 Boiler Flow Diverted From Sample Duct

[illegible]

[illegible]

Date: [illegible]

Reactor Temperature: –
Sample Substrate: –

Barometric Pressure: [illegible]
Ambient Temperature: [illegible]

Run/ Cooling	SRC	Recipient	Reactor SO_2	Reactor NO_x	Scrubber SO_2	Wet O_2	Sample* Delivery Interruption	Process ** Upset Notes
[illegible]	120	111	Flame Out	40	84	7-8%		
[illegible]	128	110		81	83			
[illegible]	122	106		73	78			
[illegible]	113	105		72	77			
[illegible]	117	105		69	79			
[illegible]	124	101		64	74			
[illegible]	128	101		63	74			
[illegible]	115	101		64	73			
[illegible]	124	98		61	72			
[illegible]	124	98		63	83		F	
[illegible]	133	101		64	74			
[illegible]	117	96		58	67			
[illegible]	106	87		51	51			
[illegible]	119	90		65	57			
[illegible]	122	84		59	55			
[illegible]	115	81		2	65			
[illegible]	116	88		54	51			
[illegible]	110	82		58	67	5%		
[illegible]	108	78		-	51			
[illegible]	108	79		-	-			
[illegible]	104	75		-	-			
[illegible]	101	75		-	-			
[illegible]	96	74		-	-			
[illegible]	79	73	"	-	-	"	"	

Note: Reactor calibration times are underlined.

Wet Flue Outlet: –
Wet Moisture: –

* Sample Delivery Notes: F = Process Sample Line
(does not apply to SRC) I = Leak in System; Diluted Sample
U = Other Sample Flow Interruptions

** Process Upset Notes: 1 = SO_2 Scrubber Down
2 = SO_2 Scrubber Leak
3 = SO_2 Scrubber Flow Diverted
From Sample Duct

[illegible]

[illegible]

Date: [illegible] Reactor Temperature: [illegible]°F Barometric Pressure: [illegible]
Sample Moisture: - Ambient Temperature: [illegible]°F

Run Number	SRC	Analyzer	Reactor SO_2	Reactor NO_x	Scrubber SO_2	Wet O_2	Sample Delivery Interruption	Process * Upset Notes
[illegible]	79	33	Flame Out	-	-	0%	F	
[illegible]	82	33		-	-			
[illegible]	87	33		-	-			
[illegible]	87	34		-	-			
[illegible]	85	34		-	-			
[illegible]	87	34		-	1			
[illegible]	92	35		-	1			
[illegible]	91	34		-	-			
[illegible]	90	34		-	-			
[illegible]	85	34		-	-			
[illegible]	103	34		-	-	-		
[illegible]						6-7%	F	
[illegible]							F	
[illegible]	105	77		59	48			
[illegible]	112	81		71	61			
[illegible]	78	75		61	33			
[illegible]	75	73		57	46			
[illegible]	92	73		58	47			
[illegible]	90	77		63	51			
[illegible]	95	73		59	49			
[illegible]	88	71		58	45			
[illegible]	93	75		63	55			
[illegible]	92	78		66	59			
[illegible]	93	79	-	66	57	-		

Note: Reactive calibration times are underlined.

Run: Flow (scfh): -
Run: Moisture: -

* Sample Delivery Notes: F = Process Sample Line
(does not apply to SRC) I = Leak in System; Ambient Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = SO$_2$ Scrubber Down
2 = NO$_x$ Scrubber Down
3 = SO$_2$ Scrubber Flow Diverted
From Sample Duct

[illegible]

[illegible]

Date: [illegible] Incubator Temperature: 75° Barometric Pressure: [illegible]
Sample Moisture: dry Ambient Temperature: 70°

Run Ending	SRT	Analyzer	Sulfates (ppm)	Sulfates (ppm)	Sulfates (ppm)	SO_2	Sample* Delivery Interruptions	Process** Upset Hours
[illegible]	[illegible]	84	Flame Out	78	61	0-72		
[illegible]	[illegible]	90		77	68			
[illegible]	[illegible]	83		77	69			
[illegible]	[illegible]	92		74	66			
[illegible]	[illegible]	95		76	67			
[illegible]	[illegible]	87		68	58			
[illegible]	[illegible]	85		62	57			
[illegible]	[illegible]	82		63	55			
[illegible]	[illegible]	92		73	66			
[illegible]	[illegible]	86		69	72			
[illegible]	[illegible]	90		74	69			
[illegible]	[illegible]	94		71	64			
[illegible]								
[illegible]								5
[illegible]	72	77		51	46			
[illegible]	68	74		51	49			
[illegible]	65	69		44	44			
[illegible]	78	68		46	43	68		
[illegible]	85	60		39	34	65		
[illegible]	80	58		28	32	58		
[illegible]	77	53		34	38			
[illegible]	78	59		39	32			
[illegible]	69	53		32	37			5
[illegible]	77	56	"	35	31	"		5

Note: Routine calibration times are underlined.

Run Flow (cubic): [illegible]
Run Pressure: 7.4

* Sample Delivery Notes: (does not apply to SRT)
0 = Process Sample Line
1 = Leak in System, Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = [illegible]
2 = [illegible]
3 = [illegible] Flow Diverted From Sample Port

[illegible]

[illegible]

Date: [illegible] Boiler Temperature: [illegible]°F Barometric Pressure: [illegible]
Sample Reference: [illegible] Ambient Temperature: [illegible]°F

Run Desig.	SEC	Analyses:	Indicated CO2	Indicated H2O	Corrected H2O	Wt. % CO_2	Sample* Delivery Interruptions	Pressure ** Upset Notes
[illegible]	70	34	Flame Out	34	29	36	1	
[illegible]	74	35		35	30			
[illegible]	74	35		33	28			
[illegible]	74	35		33	27			
[illegible]	74	36		34	29			
[illegible]	76	37		35	32			
[illegible]	74	38		35	32			
[illegible]	77	38		34	33			
[illegible]	78	42		37	33			
[illegible]	67	42		35	34			
[illegible]								
[illegible]						39-[illegible]	1	
[illegible]	96	81		95	91			
[illegible]	99	85		97	98			
[illegible]	99	90		101	101			
[illegible]	98	92		99	94			
[illegible]	99	95		104	104			
[illegible]	114	99		106	109			
[illegible]	103	102		103	104			
[illegible]	99	109		109	107			
[illegible]	96	110		103	108			
[illegible]	92	119		102	103			
[illegible]	103	131		108	109			
[illegible]	91	119	-	103	101	-		

Note: Reactor calibration times are underlined.

Duct Flow (scfh): –
Duct Moisture: –

* Sample Delivery Notes: F = Process Sample Line
(Does not apply to SEC) L = Leak in System, Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = SC Boiler Down
2 = SC Boiler Down
3 = SC Boiler Flow Diverted
from Sample Duct

[redacted]

Date: [redacted] Reactor Temperature: [redacted]°F Barometric Pressure: [redacted] in Hg
Sample Rate/min: [redacted] Ambient Temperature: [redacted]°F

Run Evening	SEC	Analyzer	Methane (CH4)	Acetylene (C2H2)	Ethylene (C2H4)	O_2	Sample* Delivery Interruptions	Pressure ** Spike Notes
[redacted]	43	[redacted]	Flame Out	[redacted]	[redacted]	[redacted]		
[redacted]	42	[redacted]		[redacted]	[redacted]			
[redacted]	0	[redacted]		[redacted]	[redacted]			
[redacted]	34	[redacted]		[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]			
[redacted]	96	[redacted]		[redacted]	[redacted]			
[redacted]	92	[redacted]		[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]		[redacted]	[redacted]			
[redacted]	134	[redacted]		[redacted]	[redacted]	[redacted]		
[redacted]								
[redacted]	[redacted]	92	[redacted]	[redacted]	99			
[redacted]	97	91	68	[redacted]	[redacted]			
[redacted]	96	90	68	[redacted]	[redacted]			
[redacted]	91	85	58	[redacted]	[redacted]			
[redacted]	82	74	77	[redacted]	[redacted]			
[redacted]	80	73	67	[redacted]	97			
[redacted]	81	75	58	[redacted]	97			
[redacted]	85	75	67	[redacted]	99			
[redacted]	78	70	58	[redacted]	95			
[redacted]	77	69	50	90	85		1	
[redacted]	76	69	58	90	83		1	
[redacted]	74	62	0	90	82	-	1	

Note: Reactor calibration times are underlined.

Duct Flow (cc/min): -
Duct Pressure: -

* Sample Delivery Codes: (Does not apply to SEC)
0 = Process Sample Line
1 = Leak in System; Diluted Sample
7 = Other Sample Flow Interruptions

** Pressure Spike Codes:
1 = O_2 Spiker Used
2 = CO_2 Spiker Used
3 = O_2 Spiker Flow Diverted From Sample Duct

[redacted]

[redacted]

Date: 1/15/76 Boiler Temperature: [redacted]°F Barometric Pressure: [redacted]
Sample Pressure: 5.0 Ambient Temperature: [redacted]°F

Hour Ending	SMC	Analyzer	Methane (ppm)	Methane (ppm)	Ventilation (ppm)	CO_2 (%)	Sample* Delivery Interruption	Pressure ** Upset Hours
[redacted]	45	52	3	84	65	13-242	1	
[redacted]	46	47	29	82	63			
[redacted]	76	55	48	96	72			
[redacted]	73	51	44	92	69			
[redacted]	69	42	40	88	66			
[redacted]	67	39	40	87	71	No Data		
[redacted]	66	33	40	86	69			
[redacted]	63	30	39	79	62			
[redacted]	58	29	29	77	59			
[redacted]	54	25	29	75	53			
[redacted]								
[redacted]								
[redacted]						13-135	1	
[redacted]	48	33	37	55	45			
[redacted]	45	31	37	48	44			
[redacted]	58	35		56	58			
[redacted]	55	36		53	53			
[redacted]	59	39		55	55			
[redacted]	65	38		52	75			
[redacted]	67	39		52	53			
[redacted]	65	44		56	65			
[redacted]	72	44		53	59			
[redacted]	62	53		66	65			
[redacted]	69	53		66	65			

Note: Analyzer calibration times are underlined.

Duct Flowrate(cfm): [redacted]
Duct Moisture: 8.1

* Sample Delivery Notes: F = Frozen Sample Line
(does not apply to SMC) 1 = Leak in System, Delayed Sample
2 = Other Sample Flow Interruptions

** Pressure Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #1 Boiler Flow Diverted From Sample Duct

[illegible]

Date: [illegible] Reactor Temperature: [illegible]°F Barometric Pressure: [illegible] in Hg
Sample Rotameter: [illegible] Ambient Temperature: [illegible]°F

Run Testing	SMC	Recipient	Reactor NO_x (ppm)	Reactor NO_2 (ppm)	Nozzle NO_x (ppm)	NO_x CO_2	Sample* Delivery Interruption	Pressure ** Taps Across Nozzle
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]

Date: 1/27/78 Boiler Temperature: 85° Barometric Pressure: 29.85

Sample Duration: .88 Ambient Temperature: 24°

Heat Ending	SRT	Readout	Initial (Min)	Initial (SCF)	Initial (SCF)	CO_2	Sample* Delivery Interruption	Process** Upset Notes
0100	80	85	Plant Out	71	80	13-14%		
0200	76	81		74	85			
0300	71	85		75	91			
0400	62	88		65	81			
0500	58	85		62	77			
0600	48	75		55	67			
0700	47	69		51	62			
0800	46	68		53	61			
0900	44	66		49	56			
1000	46	67		51	58			
1100								
1130	51	46		52	44	9%		
1200	47	35		53	44			
1300	45	34		50	39			
1400	38	33		49	37			
1500	49	33		55	42			
1600	50	34		57	43			
1700	50	35		58	42			
1800	49	35		56	35			
1900	49	36		52	36			
2000	43	37		53	34			
2100	387	37		55	73			
2200	1346	37		54	36			
2400	339	35		56	38			

Note: Routine calibration times are underlined. Duct Flow (actual): --

Duct Resistance: --

* Sample Delivery Notes: F = Frozen Sample Line
(Does not apply to SRT) I = Leak in System, Diluted Sample
O = Other Sample Flow Interruptions

** Process Upset Notes: 1 = EC Boiler Down
2 = EC Boiler Down
3 = EC Boiler Flue Diverted From Sample Duct

[illegible]

Date: 3/28/78 Tracker Temperature: --
Sample Number: --
Barometric Pressure: 30.37
Ambient Temperature: 74°

Run Timing	SSC	Analyst	Analyzer #1100	Analyzer #1200	Analyzer #1300	NDIR CO_2	Sample Delivery Interruption	Pressure Upset Notes
0100	701	35	Flame Out	33	39	92	1	
0230	1329	35		36	43			
0400	1348	36		31	39			
0525	402	38		32	41			
0650	1075	42		32	42			
0805	42	46		42	38			
0940	42	41		46	39	-		
1055	705	34		44	37	74		
1215	295	34		36	38	85		
1340	35	37		43	36	95		
1505	35	36		42	34	95	-	
1625	35	40		31	9	88	1,7	
1745	36	42		39	8			
1910	32	40		38	7			
2030	31	37		38	3			
2200	34	35		38	2			
2320	34	35		38	4			
2440	38	36		38	5			
2600	38	36		43	5			
2725	44	36		38	4			
2850	34	37		38	6			
2960	47	38		38	7			
3080	44	38		38	6	-	1,7	
3160	42	38	-	38	6	-		

Note: Analyzer calibration times are underlined.

Duct Flow (cm/h): --
Duct Moisture: --

* Sample Delivery Notes: (does not apply to SSC)
0 = Process Sample Time
1 = Leak in System, Diluted Sample
2 = Other Sample Flow Interruptions

** Pressure Upset Notes:
1 = 02 Roller Down
2 = 02 Roller Down
3 = 02 Roller Flow Diverted From Sample Duct

Date: 1/29/79 Ambient Temperature: 65°
Sample Moisture: -

Barometric Pressure: 30.38
Ambient Temperature: 17°

Hour Ending	SRC	Set-Point	Reactor 6605	Reactor 6619	Ozone 6625	NOx O_3	Sample* Delivery Interruption	Process** Upset Notes
0100	45	38	Plane Rec	20	8	NC	L,F	
0200	36	44		32	27			
0300	44	47		37	28			
0400	47	41		36	8			
0500	35	40		33	9			
0600	36	46		35	9			
0700	35	41		35	11			
0800	37	42		38	11			
0900	34	41		36	7			
1000	38	41		33	9			
1100	37	42		31	7	-		
1200	44	39		28	3	-		
1300						-		
1400						-		L,F
1500	41	42	-			3		
1600	29	31	0	26		2		
1700	34	33	0	29	4	3		
1800	37	38	7	35	2	3		
1900	34	0	0	36	0	3		
2000	37	0	1	39	-	0		
2100	39	7	10	35	-	0		
2200	31	0	10	36	-	0		
2300	36	7	10	36	0	0		
2400	33	7	10	39	1	0	L,F	

Note: Reactor calibration times are underlined.

Duct Flow (scfm): -
Duct Moisture: -

* Sample Delivery Notes: F = Process Sample Line
(Does not apply to SRC) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = SO$_2$ Boiler Down
2 = NO Boiler Down
3 = SO$_2$ Boiler Flow Diverted From Sample Duct

DATA SHEET
FIELD VALIDATION OF SAMPLE HANDLING PROCEDURES

Date: 4/29/76 Boiler Temperature: 90°F Barometric Pressure: 30.25
Sample Pressure: A Ambient Temperature: 70°F

Hour Ending	SSC	Enclosure	Enclosure SO_2	Enclosure SO_3	Bottle SO_3	SO_2	Sample* Delivery Interruption	Process** Upset Notes
0100	28	7	25	26	3	0	1,2	1,2
0200	35	6	24	26	4	1		
0300	31	6	25	25	3	0		
0400	34	9	1	26	6	1		
0500	255	185	26	250	215	1		
0600	243	53	25	95	95	1		
0700	41	15	Flame Out	26	4	0		
0800	75	17		30	23	0		
0900	35	15		26	3	0		
1000	32	11		26	4	0		
1100	41	11		26	5	0		
1200	200	10		199		-	1,2*	
1300						7	2	
1400							2	2
1500	75	72		45	40			
1600	40	55		38	29			
1700	35	51		40	30			
1800	70	50		42	32			
1900	35	53		43	35			
2000	38	60		38	44			
2100	34	58		47	40			
2200	69	55		43	36		1	
2300	57	43		32	23		1	
2400	35	40	"	32	25	"	1	

Note: Routine calibration times are underlined.

Duct Flow Leaks: -
Duct Moisture: -

* Sample Delivery Notes: (Does not apply to SSC)
0 = Pressure Sample Line
1 = Leak in System, Diluted Sample
2 = Other Sample Flow Interruptions

** Process Upset Notes:
1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flue Diverted From Sample Duct

[illegible]

[illegible]

Date: [illegible] Trailer Temperature: [illegible]°F Barometric Pressure: [illegible] in. Hg

Sample Number: [illegible] Ambient Temperature: [illegible]°F

Hour Ending	EST	Equipment	Inches H2O	Inches H2O	Cu.Ft.	MCF	Sample* Delivery Interruption	Process ** Upset Value
[illegible]	57	39		32	20	7	1	
[illegible]	55	37		31	18			
[illegible]	42	36		32	16			
[illegible]	35	34		32	17			
[illegible]	34	35		32	16			
[illegible]	35	36		31	15			
[illegible]	41	37		32	15			
[illegible]	37	35		32	17			
[illegible]	33	35		32	13			
[illegible]	34	33		32	11			
[illegible]	34	33		32	12			
[illegible]							1	
[illegible]							1	
[illegible]								
[illegible]	55	39	32	31	16	13-1/2		
[illegible]	55	42	38	39	20			
[illegible]	54	42	33	39	21			
[illegible]	47	43	33	33	20			
[illegible]	50	43	35	35	19			
[illegible]	39	44	38	35	20			
[illegible]	51	44	35	35	20			
[illegible]	53	44	32	35	21			
[illegible]	52	44	33	32	19			
[illegible]	51	42	33	31	20			

Note: Baseline calibration values are underlined.

Duct Flow Inches: -

Duct Velocity: -

* Sample Delivery Notes: F = Process Sample Line
(Does not apply to EST) L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flow Diverted
From Sample Duct

[illegible]

[illegible]

Date: 1/22/79 Trailer Temperature: 68°F Barometric Pressure: 29.75

Sample Moisture: - Ambient Temperature: 21°

Time Filling	SRC	Exchanger	Reformer #2020	Reformer #2021	Scrubber #2023	CO_2	Sample* Delivery Interruptions	Pressure ** Upset Action
1310	38	42	23	31	28	13-14%		
1330	43	43	23	30	28			
1410	43	44	23	30	28			
1430	44	42	24	29	26			
1510	51	42	24	29	27			
1530	47	44	24	31	28			
1550	38	42	24	27	25			
1610	36	41	24	25	25			
1630	36	40	23	25	24			
1650	37	41	23	26	25			
1710	41	42	24	27	24	-		
1730						13-14%		
1750								
1810	34	111	42	126	85			
1830	55	94	72	108	95			
1850	48	92	62	91	80			
1910	44	87	62	85	75			
1930	35	78	62	85	74			
1950	40	88	62	85	72			
2010	38	83	57	79	67			
2030	44	81	57	81	69			
2050	44	96	57	79	69			
2110	74	93	57	77	68			
2130	76	91	55	76	69	-		

Note: Reactor calibration times are underlined.

Duct Flow (scfh): -

Duct Moisture: -

* Sample Delivery Errors: 0 = Proper Sample Line
(does not apply to SRC) 1 = Leak in System, Diluted Sample
2 = Other Sample Flow Interruptions

** Pressure Upset Errors: 1 = #1 Boiler Down
2 = #2 Boiler Down
3 = #2 Boiler Flow Diverted
from Sample Duct

[redacted]

[redacted]

Date: 1/22/79 Boiler Temperature: --
Sample Moisture: --
Barometric Pressure: [redacted]
Ambient Temperature: [redacted]

Run Log	SEC	Analyzer	Reference (NO)	Reference (NO2)	Baseline (NO2)	NO2 CO_2	Sample* Delivery Interruptions	Process ** Upset Notes
[redacted]	30	49	52	76	73	13-15%		
	256	45	51	47	69			
	773	45	46	74	67			
	561	55	52	76	72			
	578	57	52	75	68			
	1046	54	47	71	66			
	9	48	47	61	63			
	437	37	42	61	60			
	11	36	42	61	62			
	15	37	47	64	65			
	42	37	47	67	68			
	108	37	46	67	67			
	108	37	53	69	69			
	129	42	51	69	68			
	133	34	53	72	69			
	67	38	62	81	95			

Note: Baseline calibration values are underlined.

Duct Flow Inches: --
Duct Measures: --

* Sample Delivery Notes: (does not apply to SEC)
F = Frozen Sample Line
L = Leak in System; Diluted Sample
I = Other Sample Flow Interruptions

** Process Upset Notes:
1 = 0% Boiler Down
2 = 0% Boiler Down
3 = 0% Boiler Flow Diverted From Sample Duct